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"Two Speed" Melting Shop Management—or Steady Average

By Walter Lister.

Intensive production on short runs may be admirable, but what about the average over a long period? Hard driving means increased repair stoppages which swamp the initial advantages of a record output.—Personal supervision is essential to high average production.

THE shop manager who can keep his furnaces in commission for the maximum length of time, at a steady average output, is the one who will make profits. The two-speed type of management, operating on the principle of work a week and stop a week, is of little use. I have often heard of wonderful records being made on one particular furnace for one week, but I have never heard of the same people rushing into print with the average for the year's run—simply because the stoppages for repairs, due to hard driving for a short period, have swamped what initial advantage may have been gained from the record outputs. And if a large proportion of the record output is unsaleable, which very often is the case, the ultimate result is still worse.

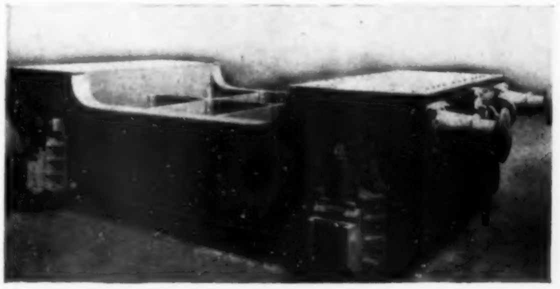
The proper upkeep of furnaces and quality of output are better than questionable records and doubtful products any time. I do not mean that any slackness should be encouraged. On the contrary every effort should be made, by efficient handling of material, scientific production of gas, etc., to save every possible minute of time: but there is a limit beyond which no furnace should be driven, or the consequences will be exactly opposite to the hopes and results desired.

For instance, a melter, in the feverish desire to create a record and, incidentally, augment his own pay-roll, will perhaps neglect bottom repairs for a charge or two. The sample-passer, also imbued with the same spirit, will turn a blind eye to a bad place. The shop manager, more often than not, is far too busy with things that don't matter to notice the condition of the furnace. And what happens? It is very likely that the following week a charge will find its way through the bottom instead of the more usual tap-hole, and the wonderful record of the week before is effectually counteracted.

Then again, there is the question of the preservation of the brickwork. Of course, the way to keep the brickwork intact indefinitely is to keep the gas out of the furnace; but all the same, linings, blocks, and roofs are often burned down prematurely and unnecessarily in the desire to make a big splash, which, like every other splash, can only be short-lived. But the furnacemen are not so much to blame for all this as the management. Sample-passers are part of the management, of course; but, as I have mentioned before, they are liable to turn a blind eye to a bad place in the bottom or to a number of bricks in a port end. Moreover, having strong trade-union sympathies, if they do notice any neglect in this respect it seldom reaches the ears of the shop manager.

It is therefore absolutely necessary that the shop manager should observe things for himself, and not rely too much on the sample-passers. But I am afraid there are many managers who seldom look in a furnace at all, and certainly never to examine brickwork, until the furnace is shut down for repairs. They leave everything to the sample-passers, and are in consequence often badly let down.

I well remember a case in point that came under my notice not so very long ago. A new manager was appointed whose sole idea of management was output—but output regardless of upkeep. He pushed the sample-passers, who in turn pushed the melters, who in their turn worked the furnaces hard in the effort to get increased output. The manager hardly ever looked in a furnace himself; all he was concerned about was the weekly tonnage sheet.



Pocket Ingot Bogie. Ingots are placed Vertically in the Pockets, providing an Easy and Quick Method of Transporting Ingots.

Well, for just three weeks there were record outputs, and then first one roof collapsed and then another. One furnace had three new roofs in as many weeks. A charge broke through the bottom of another one, and the hearth took three days to repair afterwards; it had to be almost completely washed out. Linings and port ends were all in rags, and the whole plant was in such a state that the initial success of the first three weeks was suddenly turned into a disastrous loss.

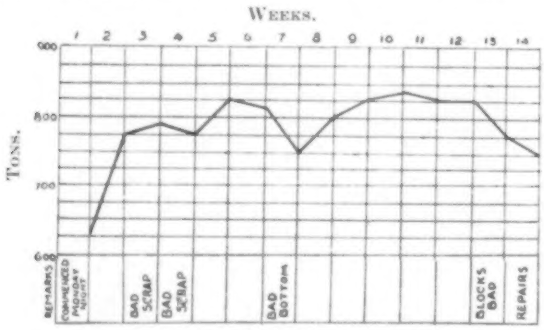
A manager who was in the habit of inspecting the furnaces for himself would never allow this sort of thing to happen. The increased output could probably have been obtained by a reorganisation of methods, both as regards the handling of material and the working of the furnaces without having to resort blindly to extreme temperatures. All other things being satisfactory, a furnace can only work up to the limits of its refractories, and it should never be driven beyond this. If the output is not satisfactory, then the design of the furnace is at fault.

To ensure a respectable life for the refractories a system of observation should be religiously carried out every day.

A good plan is to examine the ends of every furnace immediately on arrival. It is an easy matter to make a note of the condition of the blocks and roofs. Before leaving, also, the same routine should be gone through. Whenever possible, the condition of the bottoms should be noted after tapping. If this is done, it is an easy matter to fix the blame for any neglect or carelessness on the right party, who should be penalised accordingly. If the shop manager makes a habit of this sort of thing, it keeps the sample-passers on the *qui vive* to report a fault before the manager sees it. If they know the manager won't see it they probably won't bother until the trouble has developed into a stoppage.

In addition to this the condition of the furnaces after every tap should be entered on the records, but this does not have the same moral effect on the staff as the fact that the manager is in the habit of seeing things for himself.

A very important factor bearing on the preservation of the roof, is the levelling of the ports at week-ends. Of course, any bricks that may fall down during the week should be pulled out immediately, but apart from this a cavity often forms just inside the port. At the week-end the wickets should be opened, and any holes in the ports filled in with magnesite. It also may save a roof collapse to do this occasionally during the week. It is also advisable to dry the bottom up at least once during the week, say



OUTPUT CHART, "A" FURNACE.

every Wednesday. It is not necessary to dry up completely after every cast ; it is sufficient to try the bottom with a rabble to make sure there are no holes. The tap-hole only need then be dried up and closed. But if the whole bottom is not dried up at least once during the week, with the gas off, it soon becomes soft and pasty, and a serious hole is liable to develop at any time. These remarks apply mainly to fixed furnaces. In the Talbot process the bottom is more or less protected with a continuous bath of metal, so that neither scrap nor ore can have much corrosive effect ; but even with these furnaces it is not wise to run too long without emptying the furnace and drying up.

Acid Charges.—An item that sometimes causes serious trouble in the acid process, is an unaccountable increase of sulphur in the melt. The coal in use at the producers is generally blamed for this, but it may also happen in this way : when parcels of, say, 1,000 tons or so of pig iron are bought from the makers, it is generally bought on an average analysis, which, for example, may be 0·35% sulphur. But this parcel may consist of two or three casts of different analysis. One cast may be 0·025% and another 0·045%, and there may be one as high as 0·05%, but the *average* analysis of the whole parcel may still be 0·035%. Now if this is all dumped into one heap it is easy to understand that some day the charge of an acid furnace may consist of pig-iron containing 0·05% sulphur when the specification is limited to 0·035%. To avoid this it should be insisted on that no cast of pig iron should be included in any consignment which is above the specification asked for. As an alternative, each cast should be kept separate so that the proper quantities of each can be charged into the furnace to give the required result.

It is very important also that the various qualities of scrap suitable for acid charging should be kept separate. During a run, specifications may vary from 0·03 maximum sulphur and phos. to 0·05%. The crop ends, etc., from these casts, should be kept separate and used to the best advantage. Basic electric scrap can be used more profitably in the acid open-hearth than remelting the same in the basic electric.

Basic Charges.—Almost any kind of scrap can be accepted for the basic process in all its modifications, and large quantities are bought from outside sources without any restriction as to analysis, but at the same time there should be some restriction as to physcial condition. Some scrap is not cheap at any price. I refer chiefly to the feather-weight variety which takes two or three times the normal length of time to charge and then loses about half its weight in melting down. If this sort of scrap has to be used only a small quantity should be charged in each furnace so that it causes no undue delay. Besides, it is not fair to the men on tonnage to ask them to lose time and money on this class of material.

It is advisable to insist on a high-manganese content in the iron, either in the cold or liquid state. This helps considerably in the elimination of sulphur. In hot-metal shops the mixer slags will often contain 10·00% or more of MnO. These slags should be sent to the blast furnaces in order to increase the manganese content of the pig iron. In this way the valuable manganese is made to do service over and over again.

Furnace Slags.—While there is an FeO content for basic slags, below which it is not safe to go, there is also a limit above which there will almost certainly be oxidation of the charge. With a cast, for instance, containing more than 16·00% FeO in the slag, trouble can be expected in the rolling. The steel will be weak and full of blow-holes, cracking badly and developing seams and roaks. A content of 10 to 12·00% FeO should be aimed at. A slag sample should be taken from every furnace just before tapping, and before any additions are made, so that any after trouble in the rolling can be traced to its cause and the necessary steps taken to ensure that there will be no repetition of the offence.

A high FeO content is often the result of endeavouring to get on too fast, and is as much to be deprecated as the fault of burning the furnace. In cold charging, the furnace should not be charged so hard as to require a large quantity of ore or scale, and any continued offence in this respect should be severely dealt with. It should always be impressed on the men that quality of output is the first consideration ; rushing charges down in order to make up for lost time is only aggravating the trouble, as any initial gain is usually more than wiped out by an abnormal amount of scrap in the mill.

A good way to keep a close watch on the output is to have a chart prepared for each furnace. On this the weekly tonnage is plotted, on the lines shown in the accompanying chart. By this means, any loss of output can be seen at sight, and the remarks for that particular week will give the cause of it. The chart should be made out to run for the duration of a campaign, that is, until the furnace requires to be shut down for repairs to side walls and ports, and, of course, at other times for general repairs and renewals. A broad, red line should be drawn along the point indicating a good average output, and a copy of the chart should be hung up at each furnace for the benefit of the men.

Cost of Alloys, etc.—It is worth while to keep a sharp eye on the consumption of ferro-alloys, more especially those in general use, viz., ferro-silicon and ferro-manganese. These are items that are apt to be carelessly used, but they can have a considerable influence on the cost of ingots. It is quite an easy matter to give large amounts of these alloys away for nothing. For instance, say the specification for manganese in a certain order is 0·60 to 0·70% ; it is a sheer waste of a valuable alloy to give 0·71 or 0·72%.

But this is a very common occurrence and is often overlooked entirely. The additions should be carefully calculated so as to keep the manganese content of the finished steel just above the lower limit of the specification. An increase of 0·10% of manganese means about 3½d. per ton to go on to the cost of the ingots. This is quite an appreciable amount, and there is no need to make any customer a present of it; it should be paid for.

One reason why this happens is that insufficient interest is taken in the amount of manganese in the bath before tapping. I am afraid that in many shops it is not taken into account at all. A certain fixed and definite amount is assumed for all casts, and a certain fixed and definite amount of ferro-manganese per ton is weighed out for all casts accordingly—with a little bit extra to be on the right side.

But according to the quality of scrap, pig iron, etc., used, and the degree of oxidation of the bath, the manganese content will vary considerably, and it should be estimated exactly, so that the amount necessary, and no more, is added to bring the cast up to specification. This estimation of manganese should be entered on the records along with the ultimate additions, the analysis of the pit sample, and the specification to which the cast was made.

The question of ferro-silicon additions is also very important. The minimum amount necessary to comply with the specification should be used: in this case, not only to save as much as possible on the initial cost of the alloy, but also to avoid any abnormal amount of piping in the ingot. For the cheaper classes of steel, such as rails and various other sections, it is not a paying proposition to use feeder heads; brick-topped moulds only have to suffice, and in some works they do not even go to this expense. And so it can readily be seen that any unnecessary amount of silicon will greatly increase the amount of pipe and consequent discard, and although this is not borne directly by the melting shop, nevertheless it comes back home with a label attached when the rolling mill yield is reckoned up.

Silicon is more erratic in the electric process than in the open-hearth. It is no uncommon thing to see a variation of 0·18 to 0·35% in the same order. This is due in a large measure to a reduction of silicon from the slag, but this should be found out by analysis so that unnecessary additions are not made.

Aluminium also is an expensive item and it can be much overdone. People get into the habit of slinging pounds into the ladle when ounces would do. A few hundredweights of pig iron or 10% silicon pig, rubbed through the bath before tapping, will save a lot of aluminium and ferro-alloys, and will have the additional advantage of increasing the yield. For very soft steels, such as some varieties of sheet and tube steel, wire, etc., I have found ferro-titanium to be cheaper, cleaner, and more efficacious as a deoxidiser than aluminium.

Pit Supervision.—There is always room for a large amount of careful management on the pit side. The ladle cost is usually a heavy item, but it can easily become much heavier if a careful watch is not kept. Casting temperature and condition of the slag can have a considerable effect on the life of the ladle. A high temperature and a thin slag cuts brickwork out very quickly. A thick slag at the same temperature has not such a serious corrosive effect. To keep ladle costs well in hand, therefore, the life of each ladle, in casts, should be carefully recorded; and not only the aggregate number of casts, but the cast numbers also, so that the reason for any premature decease can be traced to its source. And the source is usually the sample-passer who taps at a high temperature and with a very thin slag. Thin slags and high temperatures are neither good for the steel nor the ladle.

A careful record should also be kept of the lives of ingot moulds. An index system is best, with a card for each mould. Each mould should be numbered, and a life should be entered up for it each time it is used. In this way any inferior supplies can be weeded out.

A lot of money can be wasted in the matter of slag and rubbish disposal. Wherever possible, slag should be run into tipping ladles. This is the quickest and cheapest way of handling it, but a watch should be kept on the ladle to see that any steel that may go over with the slag is recovered. Any steel in the slag ladle is always noticeable by the bottom of the ladle becoming red hot. Slag itself does not do this.

In many works, it is not possible to use ladles, so the slag has to go into pans or on the floor; probably both. The pans can be emptied into trucks by means of a crane, but that on the floor has to be shovelled up by hand; and here is where the labour cost can rise to abnormal heights if it is not kept in check. No wheelbarrow should ever be seen on the job, nor should rubbish have to be shovelled into a truck; least of all should it ever have to be shovelled out again. All loose slag and pit rubbish should be loaded by skips into self-tipping ballast wagons.

Any ingots not on casting bogies should be sent out of the pit in pocket bogies. This is a much quicker and safer means of transport than trucks. The ingots are much easier to handle both at the pit side and at the soaking pits.

And then there is the question of handling tackle, a matter that can cause everybody concerned a good deal of worry and anxiety if not properly organised. No hemp ropes should be used on any consideration, and wire ropes only for light weights well within the apparent strength

Dewhurst Dumping Car shown in Process of Tipping.

Size of Chain.	Test Load, Admiralty Strain.			Maximum Working Load.			Test Load, Admiralty Strain on the Double.			Maximum Working Load.		
In.	Tons	Cwt.	Qr.	Tons	Cwt.	Qr.	Tons	Cwt.	Qr.	Tons	Cwt.	Qr.
$\frac{3}{16}$	0	8	2	0	5	0	0	17	0	0	10	0
$\frac{1}{4}$	0	15	0	0	9	0	1	10	0	0	18	0
$\frac{5}{16}$	1	2	2	0	13	2	2	5	0	1	1	0
$\frac{3}{8}$	1	12	2	0	19	2	3	5	0	1	19	0
$\frac{7}{16}$	2	5	0	1	7	0	4	10	0	2	14	0
$\frac{1}{2}$	3	0	0	1	16	0	6	0	0	3	12	0
$\frac{9}{16}$	3	15	0	2	5	0	7	10	0	4	10	0
$\frac{5}{8}$	4	12	2	2	15	2	9	5	0	5	11	0
$\frac{11}{16}$	5	12	2	3	7	2	11	5	0	6	15	0
$\frac{3}{4}$	6	15	0	4	1	0	13	10	0	8	2	0
$\frac{13}{16}$	7	18	0	4	15	0	15	16	0	9	10	0
$\frac{7}{8}$	9	2	2	5	9	2	18	5	0	10	19	0
$\frac{15}{16}$	10	10	0	6	6	0	21	0	0	12	12	0
1	12	0	0	7	4	0	24	0	0	14	8	0
$1\frac{1}{16}$	13	10	0	8	2	0	27	0	0	16	4	0
$1\frac{1}{8}$	15	2	2	9	1	2	30	5	0	18	3	0
$1\frac{3}{16}$	16	18	0	10	3	0	33	16	0	20	6	0
$1\frac{1}{4}$	18	15	0	11	5	0	37	10	0	22	10	0
$1\frac{5}{16}$	20	12	2	12	5	0	41	5	0	24	10	0
$1\frac{3}{8}$	22	12	2	13	10	0	45	5	0	27	0	0
$1\frac{1}{2}$	27	0	0	15	0	0	54	0	0	30	0	0
$1\frac{5}{8}$	31	12	2	17	5	0	63	5	0	34	10	0
$1\frac{3}{4}$	36	15	0	20	0	0	73	10	0	40	0	0
$1\frac{7}{8}$	42	3	2	23	0	0	34	7	0	46	0	0
2	48	0	0	26	0	0	96	0	0	52	0	0

(*Continued on page* 8.)

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part II.—Raw Materials for Melting.

In this article the author deals with the raw materials used in melting charges for pouring rolling ingots.

THE raw materials used in the production of aluminium and aluminium-alloy sheet include various grades of primary and secondary aluminium, rolling-mill scrap, manufacturing scrap returned from customers, and various alloying metals. Sheet is rolled both by producers of primary aluminium and by operators of independent mills. The latter purchase primary metal from producers and secondary metal from remelters, and may also make their own secondary metal in special reclamation departments from outside purchased scrap. Ordinarily, the melting charges are made up by blending proper proportions of pig and scrap, so as to yield the required composition of metal for rolling. This applies both to aluminium and the various alloys. The composition of primary aluminium has been given in the previous article[1] of this series. Ordinarily, metal containing 99% to 99·4% aluminium (by difference) is used in the production of first-grade sheet.

In the mill where sheet is rolled for the trade, a variable quantity of scrap, resulting largely from shearing operations, is constantly revolving. The amount of scrap arising in producing various items varies considerably, depending mainly on the size and shape of the sheet. Thus, the recovery of finished material per ingot is considerably greater when coil is made as contrasted with circle stock. Also, the scrap resulting in rolling grey plate is normally less than when rolling bright flat sheet. Mill scrap, resulting from shearing operations, discards at the mills, and rejections at the inspection bench, is returned to the furnaces and remelted in the production of rolling ingots. Manufacturing scrap, such as clippings and punch-press skeletons, hay from spinning and beading operations, and sundry pieces which arise in the fabrication of aluminium products from sheet may be returned to the rolling mill by customers. If properly handled and kept clean, customers' fabricating scrap is substantially equivalent to rolling-mill scrap, and may be charged to the furnaces without first remelting, pigging, and analysing. However, if this material contains much oil or grease, is dirty, or is likely to be contaminated by admixture of aluminium-alloy clippings, foreign metals, or otherwise, it should be melted, treated by a suitable

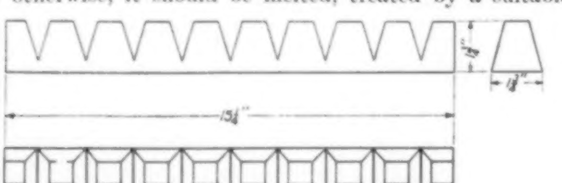


Fig. 1.—Form of Aluminium Notch Bar. (The British Aluminium Co., Ltd.).

refining process, run into pigs, and analysed. So handled, the secondary metal resulting may be used in the melting charges, being blended in proper proportions with high-grade primary metal in order to dilute impurities if required.

Secondary aluminium of satisfactory quality may be produced from market scrap, provided that such scrap is first carefully sorted and cleaned before melting. Substantial savings in metal costs may be made by the independent rolling-mill operator in the use of secondary metal made from outside purchased scrap. Thus, under normal conditions, a favourable differential of 3 or 4 cts. per pound may be obtained in the production of secondary aluminium, and if this metal must be blended half-and-half with primary aluminium, in order to dilute the impurities sufficiently, then the saving in raw material cost for the sheet is at least $1\frac{1}{2}$ to 2 cts. per pound. Generally speaking, it is not usually necessary to blend half-and-half, but a larger proportion of secondary metal may be used on the average.

Fig. 2.—Forms of Aluminium Pig.

Consequently, the saving is greater than that just indicated. Needless to say, perhaps, the independent sheet-mill operator is at a great disadvantage as regards raw-material costs in rolling aluminium sheet in competition with producers of primary metal. While the economic aspects of the matter cannot be dealt with here, briefly the situation is this: Leaving out of consideration the margin to the aluminium producer as represented by the difference between the cost of producing primary pig metal and the sales price, the differential between the cost of primary aluminium to the independent sheet-mill operator—*i.e.*, the selling price of primary metal—and the selling prices of sheet products, is generally too thin. While the primary-aluminium producer can run a sheetmill under current conditions with lean differentials between the stated market price of pig and the sales price of sheet, getting his profit from the pig, the independent mill operator cannot buy primary metal, roll sheet, and make an adequate profit. In order to stay in business, the independent operator must reduce his raw-material costs. This he can do only by the use of secondary metal and scrap.

Generally speaking, the grades of secondary 98–99% aluminium as made by custom remelters are not suitable for use in sheet production. Or, stated more precisely, there is little economic advantage in using these grades of metal because the content and nature of the impurities present are such that undue proportions of primary metal or expensive scrap, such as cable, are required in the blending. In the United States at least, central remelters cannot or do not market satisfactory grades of secondary aluminium at prices attractive to the sheet mills. Most sheet-mill operators both here and abroad have found it necessary to operate their own secondary departments for the production of satisfactory grades of remelted metal

[1] R. J. Anderson, "Aluminium Sheet Production," METALLURGIA, Vol. 2, September 1930, p. 173; October, 1930, p. 211.

from scrap. At the present time, secondary metal and scrap are being used extensively by the independent interests in the production of sheet. The primary aluminium producer who operates a rilling mill has no special problem in the matter of raw material.

Forms of Metal.

Aluminium pig for remelting purposes appears on the market in sundry forms, which vary somewhat among different producers. Both primary and secondary metal are cast into pigs of various sizes, shapes, and weights ranging from about 1 lb. to 35 lb. or more. Pigs weighing about 3 lb. and 30 lb. are convenient and usual sizes. Pigs may be cast with or without notches. Thus, large pigs may have two to four notches, and small pigs (often called notch bars) may have two to ten notches. Most producers have specially designed moulds for pouring pigs of characteristic shapes, the shapes serving as means of identification or as a sort of trade mark. It is also practice to pour alloys of various compositions into pigs with different numbers of notches, the notching thereby serving as a means of identification. A trade-mark impression may be formed on the bottom faces of the notches by means of raised letters or special insignia in the pig moulds. One other reason for making notched pigs is so that they may be broken readily by a blow, the pig fracturing through the web. There is a zone of weakness adjacent to the notch, formed by the crystallisation of the metal on freezing. Most casting alloys are rath r brittle and wi l break more or less easily at the notch. Commercially pure aluminium is relatively tough as cast, and quality metal will not break readily at a notch.

Primary-metal producers, especially the Europeans, may pour much of their market metal in inverted notch-bars—*e.g.*, a bar having ten notches, and weighing about 3 lb. Thus, Fig. 1 shows a form of notch-bar made by the British Aluminium Co., Ltd., the weight is approximately 3 lb. In tonnage rolling mills, pigs weighing about 30 lb. are generally preferred. A pig of this size is convenient for a man to handle in charging. Small pigs—*e.g.*, those weighing about 3 lb.—are bothersome to handle and charge in quantity to melting furnaces. In shipping inverted notch-bars of small size, it is usual practice for producers to wire a quantity of bars together in a bundle. A typical

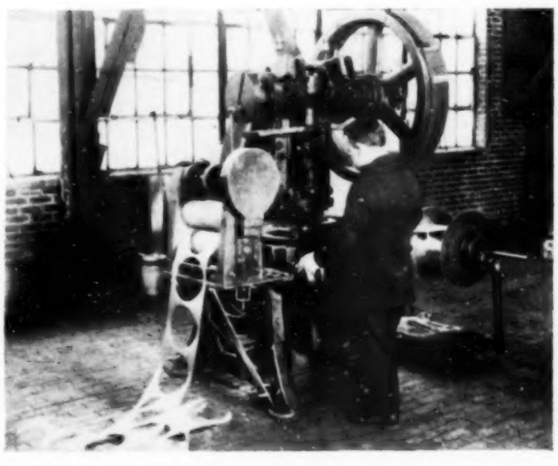


Fig. 3.—Punch-Press Operation in Making Circles from Coil.

bundle may contain about 33 bars of the 3¼-lb. size, and weigh about 110–111 lb. with the wire. While such bundles are convenient to handle in unloading from cars, the steel wrapping wires must be removed before the metal can be melted. The bundles are wired in and out through the notches, so that the bars will not slip out, and the removal of wires is a troublesome and time-consuming nuisance. Large pigs—*e.g.*, the 30-lb. size—are ordinarily shipped loose.

Fig. 2 shows three forms of primary aluminium pig. Reading from top to bottom, the pigs are as follows: 30 lb., four notch, made by the Aluminium Company of America; 15 kilogs., unnotched, made by the Vereinigte Aluminium-Werke, A.-G.; and 2 lb., 10 notch, made by the British Aluminium Co., Ltd. Various other forms are supplied by the different producers.

It should be added, in passing, that primary-aluminium producers furnish rolling ingots in various sizes to consumers. In some small mills where foil or stock for collapsible tube blanks is rolled, it may be found advisable

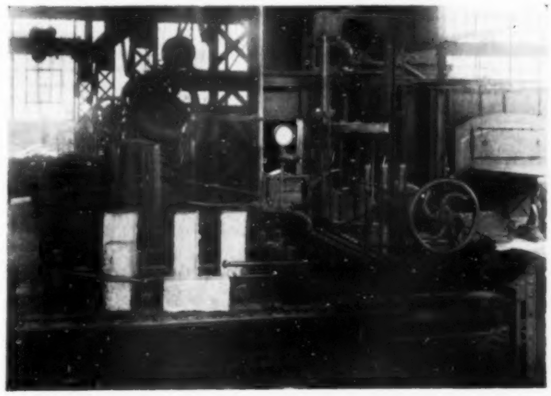


Fig. 4.—Hydraulic Baling Machine (Logemann Bros., Co.).

to purchase ingots ready for rolling rather than pig metal for remelting. However, in tonnage plants it is usual practice to produce rolling ingots from blended charges rather than to purchase such ingots from outside sources.

Forms of Scrap.

As has been pointed out above, scrap constitutes an item of considerable importance in the make-up of melting charges in the aluminium-rolling mill. Aside from outside purchased scrap which may be used in a reclamation department for the production of secondary metal, scrap utilised in the rolling mill may be classified as (1) process scrap, and (2) customer's scrap.

Process scrap includes all scrap arising in the various operations of producing finished sheet and coil products. Such scrap consists mainly of shearings and material discarded at the inspection bench as defective. In producing lots of sheet from ingots of given sizes, there is a normal percentage of scrap which arises, due to necessary shearing operations. This percentage is usually referred to as legitimate scrap. Any excess quantity over the legitimate percentages is due to variations in mill practice, faulty operations, defective metal, or other causes which need not be further considered for the present. Among other items of legitimate process scrap, the following may be mentioned: Slab crop ends, slab side shearings, pieces from squaring and finish-shearing operations, slittings produced in cutting coils to width, pieces from circle shearing, and skeletons produced in blanking circle stock from coils. All process scrap, including buckled or defective sheet pieces discarded at the mills and material thrown out at the inspection bench, is returned to the melting furnaces. Floor spatters and drippings arising in pouring ingots are returned to the furnaces. Dross and skimmings from melting may be reworked for metal or sold to remelters.

Heavy process scrap, such as slab crop ends, defective ingots, or slabs, and slab shearings, may be gathered up and charged as such. Long slab side shearings are usually cut up into short lengths for easy handling. Light scrap should be baled or bundled before being charged to the melting furnaces, since otherwise the oxidation losses will be high and the large surface area exposed will lead to undue contamination of the metal with included oxide. Light shearings may be cut up if required, and then baled

in a hydraulic baling machine, compact bundles weighing 30 lb. to 70 lb. being formed, depending on the capacity of the equipment. Long slittings and punch-press skeletons may be rolled up into cylindrical bundles. In a later article of this series the handling of aluminium rolling-mill scrap will be discussed in detail. Fig. 3 shows the skeleton discharge from a self-feeding punch press, used in blanking coils for the production of circle stock. Fig. 4 shows a small hydraulic baling machine in a rolling mill, and the bales produced thereby.

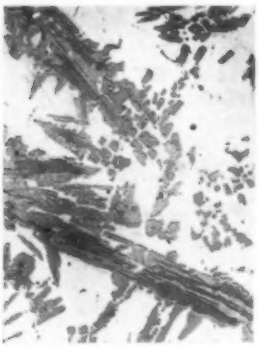


Fig. 5.—Microstructure of 10 : 90 Manganese - Aluminium Alloy; Etched NaOH and H F; ×100 (Daniels).

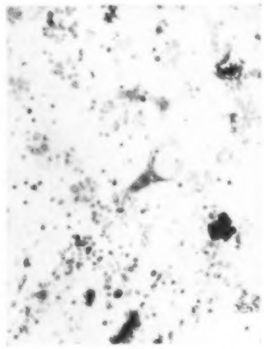


Fig. 6.—Microstructure of 50 : 50 Copper - Aluminium Alloy; Etched H F; × 100 (Daniels).

Referring to customer's scrap, as has been mentioned previously, if scrap resulting from fabricating operations in making articles from aluminium sheet is kept clean and properly handled, it is equivalent to rolling-mill process scrap. Customer's scrap may be purchased by rolling-mill operators, or, in some cases, customers regularly ship back their scrap to the mill and have an equivalent quantity of sheet rolled on toll. Thus, the scrap is regarded as being practically equivalent to pig metal except that the loss on melting will be higher. Customer's scrap may be received by the rolling mill either loose or baled. Tonnage consumers of aluminium sheet who accumulate large quantities of scrap ordinarily bale the material as fast as produced in order to save storage space in their plants. Where all the facts are known regarding the practice of customers in handling their scrap and preventing contamination, it is ordinary practice to either use such scrap in blended melting charges or simply melt the material in all-scrap charges for the production of new sheet stock on a toll arrangement. If the customer uses various aluminium alloys so that the chances for contamination are great, it is practice to remelt the scrap, run into pig, and analyse before blending in melting charges for the production of rolling ingots.

Intermediate Aluminium Alloys.

In the preparation of light aluminium alloys of various compositions for sheet rolling, certain alloying metals, either as such or in the form of intermediate aluminium alloys (so-called hardeners) are used. When metals of relatively high melting points, such as copper, manganese, nickel, and silicon, are to be added to aluminium in making light alloys, it is advisable to use an intermediate alloy as the vehicle. Metals of relatively low melting point, such as magnesium and zinc, are incorporated directly. There are definite advantages in using intermediate alloys for introducing metals of high melting point, and, in fact, their employment in general practice is ordinarily necessary to ensure good results. The intermediate alloys melt at relatively low temperatures as compared with the metal to be added, and some of them melt at lower temperatures than aluminium. Such alloys are usually brittle, so that they can be broken easily, and quantities may be weighed accurately. The intermediate alloys go into solution readily in liquid aluminium, and their use greatly facilitates alloying procedure. It is troublesome or undesirable to make fixed additions of high-melting-point metals by direct addition to aluminium. If a solid metal of high melting point is added to liquid aluminium, it requires considerable time for solution to be effected at the ordinary melting temperature. In order that the speed of dissolution may be increased, it is necessary to raise the temperature of the aluminium very considerably; consequently, heavy drossing and undesirable gassing are likely to occur. Moreover, there is danger of segregation in making light alloys by this method. Also, if a metal of high melting point is melted and poured into liquid aluminium, it may freeze in part before alloying takes place.

The principal binary intermediate alloys used in rolling-mill work include certain compositions in the aluminium-copper, aluminium-manganese, aluminium-nickel, and aluminium-silicon series. With the advent of various complex light alloys of recent years, various complex intermediate alloys have been used with the object of making fixed additions of two or more metals simultaneously. Formerly, it was practice to use intermediate alloys containing rather high percentages of the alloying metals. More satisfactory results are obtained on the whole, with leaner alloys, and present practice is tending toward the use of intermediate compositions containing relatively small percentages of the alloying constituents. For adding copper to aluminium, the 33 : 67 and 50 : 50 copper-aluminium compositions are generally favoured. When about $\frac{1}{2}$% to 1% manganese is to be added, the 10 : 90 manganese-aluminium alloy is satisfactory. Nickel may be introduced with the 10 : 90 nickel-aluminium composition. Various intermediate silicon-aluminium alloys have been used in practice. When silicon is to be added to adjust the iron-silicon ratio, the 10 : 90 silicon-aluminium composition may be used. If the 95 : 5 or 87 : 13 aluminium-silicon alloys are to be made, then intermediate alloys containing 25% to 50% silicon are preferred. Copper and manganese may be introduced simultaneously in the preparation of duralumin by the use of an alloy having the nominal composition 40 : 5 : 55 copper-manganese-aluminium. Calcium may be introduced into duralumin melts by the use of the 5 : 95 calcium-aluminium alloy or by a ternary calcium-copper-aluminium composition. Intermediate aluminium alloys have been discussed at length by the writer[2] in another place. These alloys may be made up in the rolling mill in relatively small batches as required or purchased from the usual sources. They should be poured in small pigs or thin waffle plaques. Ordinary high-grade commercial metals are suitable for use in preparing intermediate alloys.

Fig. 5 shows the microstructure of the 10 : 90 manganese-aluminium alloy, and Fig. 6 shows that of the 50 : 50 copper-aluminium alloy. Fig. 7 shows the large interlocking crystals characteristic of the latter alloy.

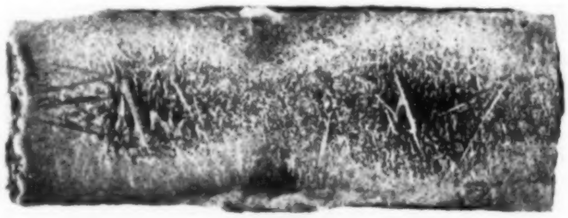


Fig. 7.—Surface Appearance of 50 : 50 Copper-Aluminium Alloy Pig; about Quarter Actual Size.

Storage and Handling.

Adequate storage facilities should be provided for housing the raw materials used for melting in the aluminium-rolling mill. In large plants, mechanical handling and transport equipment for moving pig and scrap are requisite and

[2] R. J. Anderson, "Intermediate Aluminium Alloys (Hardeners) for Use in Preparing Light Aluminium Alloys," *Amer. Metal Market* (Monthly Section), Vol. 33, July, 1927, p. 4, *et seq.*

essential. Preferably, the storage room for metal should be situated near the melting furnaces. In properly designed plants, the movement of metal from incoming cars to the furnaces should follow a straight-line layout. Thus, metal (either pig or customer's scrap) may be unloaded from cars, moved to scales for weighing, and passed to storage. When metal is withdrawn for melting, it should move in a straight line from stores to scales to the furnace. If a reclamation department is operated, secondary metal from this separate department may be stored with the primary metal and scrap. The storage room should have sufficient floor space, so that the required quantity of material which it is desired to keep on hand may be stacked on skid platforms or other movable transport equipment. The cardinal principle in the storage of heavy material which must be frequently moved is to provide facilities so that repeated handling will be avoided. Fig. 8 shows a view in a storage room in a rolling mill. It will be noticed that the pig metal is stacked on steel platforms for handling by electric truck. At the right there are bundles of inverted notch bars wired together; in the centre will be seen pigs of secondary metal, made in the reclamation department of the plant; and at the left are pigs of primary metal.

Batches of intermediate alloys for use in making up light alloys may be kept conveniently in bins or barrels, properly labelled as to contents.

In handling process scrap, it is general practice to return this material to the furnaces as rapidly as possible, thereby avoiding accumulations in the mill. Skid boxes may be used to advantage in handling and moving mill scrap. Such boxes should be placed around in the mill at convenient locations wherever scrap accumulates. As soon as a box is filled, it may be picked up by electric truck, moved to a scales, weighed, and sent to the melting-room for use in the next heat. When several different alloys are being rolled, as well as different grades of aluminium, box loads of scrap will be sent to storage or to the melting-room, depending upon what compositions of material are next to be rolled. The problem of preventing contamination of mill scrap when several compositions are in process is serious. It is usually advisable to use some easily distinguishable mark or label on scrap-boxes, and on pieces of the scrap, if necessary, to avoid mixing the different materials. The practice of painting scrap-boxes different colours has been tried, but when a shortage of boxes, coloured for one class of scrap, arises then other boxes must be used. Blocks painted various colours may be hung on the scrap boxes, the blocks being changed as required. The crop ends or sides of slabs may be marked with a dab of paint for purposes of identification. Thus, in a mill where ordinary 2S, 3S, duralumin, and 51S sheets are being rolled, the 2S may not be marked. 3S is identified with black, duralumin with red, and 51S with green.

In putting up melting charges and in moving mill scrap, fast and easy handling is necessary in tonnage plants. The method of stacking pig metal on skid platforms with movement by electric-lift truck has much to recommend it.

Baled scrap may be stacked on skids or loaded in boxes and similarly moved. Scrap boxes may be made of wood or of steel construction. Wooden boxes are subject to much breakage, and the maintenance cost is high. Steel boxes are more satisfactory and less expensive in the long run, although the first cost is more than that of wooden boxes.

Fig. 8.—View of Pig Storage.

Melting Charges.

In making up melting charges for the production of aluminium and aluminium-alloy sheet the composition of the metal is controlled according to the quality of material desired or to some definite specifications laid down by the consumer. The usual charge is made up by blending various proportions of primary metal, mill scrap, customer's scrap, and secondary metal. In some plants only primary metal and mill scrap may be used, or specifications may require that only primary metal plus scrap originating in the rolling shall be used. In some cases it may be necessary to run some heats of all-primary metal, while in other cases heats of all-mill scrap are melted. Metal rolled on toll may consist of all scrap, returned by a customer. While a more or less definite quantity of process scrap arises in the rolling operations, an undue proportion may result at times, due to high rejections on inspection. At such times, the melting charges will carry a higher percentage of scrap in relation to pig than under normal conditions. The quantity of legitimate scrap resulting in rolling alloys is higher than in rolling commercially pure aluminium. Consequently, more process scrap is to be returned to the furnaces in rolling duralumin, for example, than in rolling 99+% aluminium. While mill or customer's scrap is usually regarded as substantially equivalent in composition to the melting charge from which derived, the content of impurities may be expected to be slightly increased by contamination from the furnace and furnace tools. Ordinarily, this contamination is of no practical consequence.

In some plants it is practice to designate melting charges (and rolling ingots poured therefrom) by suitable symbols, according to the proportions of contained primary metal and mill scrap. Thus, in one plant charges are designated as A, B, C, D, and E, and the subjoined table shows how the percentages of primary pig and scrap may vary :—

Ingot Designation.	Percentage. Primary Metal.	Mill Scrap.
A	100—80	0—20
B	80—60	20—40
C	60—40	40—60
D	40—20	60—80
E	20—0	80—100

Accurate record should be kept of the weights and kinds of material used in each heat. This is readily taken care of by the weighman when the charge is put up, proper notation being made on a separate sheet for each charge. If trouble arises in the processing of lots, it is an easy matter then to refer back to the charge sheet and see what material went into the heat.

While ordinarily first-grade rolling ingots in 2S metal are understood to have been poured from a charge of all-primary aluminium plus mill scrap originating in the processing of material of the same composition, it will be readily understood that ingots of equivalent quality may be poured from properly blended charges of scrap and pig of either primary or secondary origin. Thus, the content of impurities in a melting charge made up of secondary aluminium, derived from old cable containing 99·7% aluminium, and mill scrap may be less than the content of impurities in an all-primary charge. The quality of rolling ingots, aside from soundness and good structure, is determined by the composition and freedom from dissolved gases and foreign included matter. Whether the metal from which they are made is primary, secondary, or scrap has no bearing on the situation. The presence of certain impurities, in subordinate amounts at least, appears to result in no special difficulties on rolling or impair the mechanical properties of the sheet. Of course, it will be appreciated that if a melting charge contains a high percentage of loose light mill scrap, and if the melt is not properly treated by fluxing or so-called refining methods considerable occluded dross is likely to be found in the sheets. Consequently, sheets made from such a charge would not have so good a surface appearance as sheets rolled from an all-pig melt. Formerly, it was practice to reduce the quantity of scrap carried in the melting charge when large bright sheets were to be rolled, and high scrap heats were run for the production of coil. With the advent of degassing methods in melting practice, it has been found that very satisfactory wide bright flat sheet may be produced from melts containing large proportions of process scrap.

In the next article of this series the type of furnaces used in melting for the production of rolling ingots will be discussed.

"Two-Speed" Melting Shop Arrangement or Steady Average.

(Continued from page 3.)

of the rope. A wire rope has the disadvantage of having to be spliced or knotted, and this part is not always to be depended on. Moreover, a few strands are liable to get burnt in handling hot material, and this may cause the rope to give way at any time.

Chains are always best and safest. But it should be brought to the notice of the personnel of the pit side exactly what size of chain is required to lift with safety any particular weight. I append a list of chain sizes and their maximum lifts in the hope that it may be put to some practical use and accidents avoided.

If this is posted up in a prominent place, it should be considered a crime to try to lift any weight above the maximum working load of the chain. All chains should be annealed periodically at, say, intervals of three months, in order to normalise the structure and remove undue stresses.

As a last word of a very brief survey of an important subject, I must once more emphasise the necessity for personal supervision in the melting shop. The most elaborate system of office management, records, costs, etc., fails entirely to make profits unless it is combined with the personal touch of practical supervision.

CRUCIBLE DEFECTS.

THE useful life of crucibles varies very considerably. The length of service that may reasonably be expected depends upon the compositions used, their melting temperatures, and the effect the fluid metal may have on the crucible. Crucibles are subject to a number of defects which influence the cost of production according to the manner in which they are used. Apart from the shelling-off of the exterior of the crucible, sometimes known as a scalp, the most serious defect is what is known as pinholes or a leaky crucible. The cause of this trouble is much more difficult to locate than with a scalp, as there are so many causes responsible for it. Improper or hasty annealing will sometimes permit a crucible to enter the furnace without showing any indication of a fracture. At the same time, the fracture is there, and after a few heats, the metal will follow it, sometimes finding an exit several inches from where it started. This is the most common form; it seldom happens that a pinhole makes a direct passage through the crucible wall unless it was worn very thin. Some crucibles which have developed pinholes after a few weeks will, when broken up, show a network of metal woven into the wall. A condition of this kind invariably indicates that the crucible was too hastily annealed, which caused an internal fracture that did not develop into a scalp or the annealing process may not have been sufficiently completed to prevent an internal fracture after it was placed in the furnace. Certain kinds of fluxes are directly responsible for pinholes, forming, as they do, chemical combinations with the metal which attack the crucible, and cause a leak. Some compositions, particularly phosphor bronzes, have a remarkable searching effect when in the fluid state, and cause penetration into the structure of the crucible, which, when worn thin, invariably shows pinholes.

The improper stoking of a coke furnace is also responsible for pinholes, particularly when the temperature is high, as the crucible is comparatively soft when very hot, and forcing coke against it in such a condition hastens the connection with any internal fracture which may be present. Even gas- or oil-fired furnaces are not immune in this respect, although the effect on the crucible is not so severe as with coke. When the flame impinges the crucible, though it may resist shelling, pinholes will eventually develop. A bad mixture of air and gas is also detrimental to the crucible, particularly when the air volume is too great and a graphite crucible is used. In such cases, free oxygen acts upon the graphite, and reduces the crucible, which makes it subject to pinholes. Improper handling and bad fitting tongs are other causes of defects; local fractures are produced, and the metal soon finds an outlet.

Although the average user of crucibles may be familiar with many of the causes of defects which have been mentioned, the fact that the scrap metal may be the cause is not so generallly known. Impurities are introduced into the crucible with the scrap metal which is to be melted; and scrap varies in its impure conditions and its degree of possible effect upon the metal and the crucible. Sometimes scrap may be employed which has been taken from chemical works or has been used for conveying matter which has corroded or left a residue on the interior of the scrap metal. Such scrap metal very often has a pernicious effect upon the crucible, and it soon develops defects. Occasionally a rotten lot of scrap which carries a cyanide, is dumped into the foundry and, as cyanide attacks crucibles and forms pinholes, the useful life of crucibles, however good they may be, or however carefully they may be annealed, is considerably reduced.

Owing to the demand for Back Numbers of Metallurgia, we are unable to supply copies for January, April and June, and would be glad to hear from any of our readers who are desirous of disposing of their copies of these issues.

METALLURGIA

The British Journal of Metals.

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

BE READY FOR TRADE RECOVERY.

THE amalgamation of undertakings has for some time been advocated as an effective means of putting the various staple industries into a better position to meet competition. The most recent merger of this character is that between the coalowners of Lancashire and Cheshire. The significance of this step is indicated by the fact that the decision affects about 85,000 colliery workers, and represents a capital estimated at £20,000,000. It may be considered largely a defensive measure, as the home markets of the interests represented in the new merger have previously been attractive to Yorkshire and Derbyshire mines. To the public, as well as to the mining areas where amalgamation has not made much progress, the North-West merger indicates a faith in reorganisation, since it represents the largest experiment of its kind yet attempted.

Amalgamations have, of course been effected in the iron and steel industry, primarily with the object of increasing efficiency and cheapening production costs. Great efforts have been made to overcome arrears of installation and improvements which accumulated during the war, in addition to renewals constantly demanded to maintain plant in a thoroughly equipped condition. Reorganisation of this kind has effected considerable saving in the cost of production when circumstances warrant the plant operating at full capacity. Unfortunately, the modernising of plant has resulted in over-production, not only in this country, but also abroad, and a reduction in output is unremunerative in view of keen competition from abroad. Rationalisation is costly, and as a result of the continued depression is bringing no return; as a matter of fact, some firms will be in a worse position temporarily than prior to reorganisation. Logically, rationalisation to be of any real value should be carried from one end of the commercial scale to the other. Frequently the cheapening in cost of producing semi-finished materials is lost through faulty organisation in the various processes involved in producing a commodity and subsequently conveying it to the purchaser; but there is no doubt that the high costs carried by British manufacturers in the face of a world fall in prices is favouring the continuance of the present industrial depression. The majority of our overseas customers are agricultural countries, and entering into competition with us are other countries whose costs are less than are operative in this country.

It must not be forgotten that we spend £271,000,000 a year on social service, twice what Germany spends per head of her population, six times as much as France, and 25 times as much as Italy. Further measures are being considered by Parliament, which, if they become law, will considerably increase the expenditure on social service. We are not concerned at the moment with the object of these measures, as it does not follow that the various forms of expenditure are ill-advised in themselves, but the real question is whether we can, under the present circumstances, afford to make further calls upon an already overburdened exchequer. The world is passing through an economic revolution, and we must tread warily to hold what has been won. The future can be only dimly foreseen, and the utmost care is necessary to steer our industries to a secure position in the new conditions which will ultimately emerge. Rationalisztion may result in hardship and temporary unemployment, but no reduction in taxation or reduction of wage rates are likely to retard the process, which involves the elimination of unnecessary competition, the writing-off of capital and loans that have been lost, the re-equipment of industries that are technically backward, the search for new products, new methods, and new markets.

The suggestion made to the Imperial Conference by the Federation of Chambers of Commerce of the British Empire is an important one. It consists in the creation of an Imperial General Economic Staff, whose duty it would be to formulate plans for commercial developments, and, when approved by the constituent nations of the Empire, should be stabilised for a reasonable period. The Federation was evidently considered to be sufficiently representative and authoritative to justify a departure from established custom, as a memorandum was presented to the Ministers of the Dominions and Great Britain at the Board of Trade recently. The memorandum urged that none of the 54 units in the Empire could achieve its highest destiny by individualist policies, but that in unison they could become the greatest economic force in the world and that effective co-operation could only be established by a scientific adjustment of inter-Empire tariffs.

Another suggestion, put forward with considerable assurance, and which has for its object the resuscitation of the iron and steel industry, is to use part of the unemployment fund as a subsidy to enable manufacturers to meet foreign competition. Each of these suggestions depends primarily upon political influence and bristles with difficulties, and however valuable either may be, it would be a distinct misfortune if any of our industries delayed reorganisation in the expectation of some form of subsidy or protective tariff. There is no sound reason for delay in making each industry more efficient economically, so that each in its special sphere will be better able to meet foreign competition. Reorganisation is an economic question entirely within the control of industry, and to be in readiness for a definite trade recovery, which is not likely to be long delayed, will enhance the possibility of the various industries competing successfully for its products as opportunities arise. Should some form of protection or subsidy be subsequently granted, any advantage would be additional to advantages resulting from rationalisation.

FORTHCOMING ISSUES WILL INCLUDE THE FOLLOWING ARTICLES :—

Special Steels in Marine Engineering and Shipbuilding.
High-speed Steel at Elevated Temperatures.
Normalising Steel.
The Grunewald Clean-annealing Process.
Aspects of Carbon Control in the Cupola.
The Modern Blast-furnace and its Operation.
Hot-mill Practice in the Production of Aluminium Sheet.
Influence of the New Alloys on Machine Tools.
Repairs to Steel Melting Furnaces.
Special Non-ferrous Metals used in Marine Engineering.
Welded Steel Structures.
Bronze Gears and their Production.

FIRST ANNIVERSARY.

THIS issue of METALLURGIA represents the first anniversary of its publication, and in view of the widespread interest it has created, it is perhaps opportune to consider the function of the journal from the initial issue and as a result of experience from the past year. In the first editorial we said, "There is no excuse for the production of journals that have not a definite policy and that do not meet a need." The primary object in publishing METALLURGIA was to form a bridge between the laboratory and workshop, to consider metal in all its forms, from production in the crude condition through the various operations, including machining and heat-treatment of metals, to finished components and complete assemblies, and to cover all forms of equipment which the necessary processes involve. Few there are who do not appreciate the fact that the various departments, including the foundry, forge, mill, and machine shop, are no longer divorced one from the other in interest. Metallurgy has come out of the laboratory and has invaded the various departments, and as operations themselves become specialised, the need for a general unifying source of information arises to connect these various operations. This was METALLURGIA'S original aim, and strenuous efforts have been made to adhere to it and, at the same time, to bear out the statement made in the original issue, which reads: "There is no reason why a high-class technical journal should not reach the standard of a really beautiful production."

That the publication fulfils a need is clearly indicated by the numerous congratulatory letters received, not only from prominent metallurgists in this country, but from many parts of the British Empire, as well as from the Continent and America; but probably a better criterion is the phenomenal number of subscribers who have enrolled, and whose numbers are continually increasing. Further, it is of interest to mention the requests being received for back numbers of the journal. These requests are being made with remarkable regularity, and although unusual precautions were taken in view of a possible demand, they have been totally inadequate, and, in the case of many issues, we regret our inability to supply further copies. In addition to encouraging appreciation, many correspondents have been frank in their criticism. Opinions will necessarily differ, but we appreciate constructive criticism—the reduction in the cost per copy of this and succeeding issues is a direct result,—and welcome the views of readers either in the form of letters or more lengthy contributions. We take this opportunity of thanking all those who have so ably contributed during the year, and who have materially assisted in the production of a journal which can rightly claim to be of a high order. We are encouraged to press forward and continue to produce a journal worthy of the great industries it represents and of outstanding value in British technical publications. With this object in view, we have no hesitation in asking for the continued co-operation of our readers; the results of the first year justify the belief that we shall not be disappointed.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Nov. 21. "The Coefficient of Heat Transfer from Tube to Water in Surface Condensers," by A. Eagle, B.Sc., and R. M. Ferguson, M.Sc.

Dec. 5. "Machinery and Methods of Manufacture of Sheet Glass," by Professor W. E. S. Turner, O.B.E., D.Sc.

Dec. 12. "X-Ray Methods in Engineering Practice," by V. E. Pullin, O.B.E., B.A., B.Sc.

INSTITUTE OF METALS.

Nov. 20. London Section. "Some Non-Ferrous Metals in Chemical Engineering," by Richard Seligman, Ph.Nat.D. (Meeting at the Royal School of Mines, South Kensington, S.W.)

Nov. 27. Birmingham Section. "Solders," by O. F. Hudson, D.Sc.

Dec. 2. Scottish Section. Open night.

Dec. 9. North-East Coast Section. "Properties of Coke," by Professor H. V. A. Briscoe, D.Sc.

Dec. 11. Birmingham Section. "Plating," by E. J. Dobbs.

Dec. 11. London Section. "Magnesium and Alloy Castings," by E. Player. (Meeting at Edibell S. F. Apparatus, Ltd., 89-91, Wardour Street, W. 1, at 8 p.m. Joint meeting with Institute of British Foundrymen.)

Dec. 12. Sheffield Section. "Studies in the Electrodeposition of Silver; Throwing Power; the Behaviour of Silver Anodes, with special reference to Blackening and its Prevention," by R. H. D. Barklie, M.Sc., and A. E. Nicol.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

Nov. 28. "The Ocean-going Tramp Steamer from the Owner's Point of View," by W. Stanley Hinde.

Dec. 12. "Refractories for Boiler Furnaces," by W. J. Rees, B.Sc.Tech., F.I.C. Lecturer in Refractory Materials, University of Sheffield.

TEES-SIDE BRANCH.

Nov. 20. "Ship Repairing," by G. Tristram Edwards, Vice-President.

Dec. 11. Discussion: "Shipbuilding in Japan and Russia," to be opened by J. Crichton, member, and F. A. Cocks, B.Sc.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Nov. 24. "Apprentice Training." A. E. Berriman, Coventry.

Dec. 11. "The Preparation and Handling of Moulding Sand," by W. E. Box, Birmingham.

EAST MIDLANDS BRANCH.

Dec. 13. Paper by W. Molineux, Braintree (at Derby).

LANCASHIRE BRANCH.

Dec. 6. "Foundries—and Foundries," by S. H. Russell, Leicester, Past-President of the Institute.

LONDON BRANCH.

Dec. 11. "Magnesium Alloy Castings," E. Player, Coventry. (Joint meeting with London Section, Institute of Metals.)

MIDDLESBROUGH BRANCH.

Dec. 12. "Foundry Practice Abroad: Some Personal Reflections." J. G. Pearce, Birmingham.

SCOTTISH BRANCH.

Dec. 6. Afternoon: "The Production of an Aluminium Alloy Casting." A Harley, Senior Vice-President of the Institute, Coventry.

SHEFFIELD BRANCH.

Nov. 21. "Air-Hardening and Oil-Hardening Cast Iron." J. E. Hurst, Chesterfield.

Dec. 10. "X-Ray Examination of Castings," by V. E. Pullin, O.B.E., D.Sc.

WALES AND MONMOUTH BRANCH.

Nov. 29. "Jobbing, Moulding and Its Relation to the Engineer." S. Southcott, at Bristol.

Dec. 13. "Studies in Foundry Sands." J. Hird, at Newport.

WEST RIDING OF YORKSHIRE BRANCH.

Dec. 6. "Some Aspects of Modern Foundry Practice." F. Griffiths.

THE INSTITUTION OF WELDING ENGINEERS.

Dec. 11. Paper by C. C. Hall, Esq. "The Fabrication of Plant in Acid-resisting Steels." At the Institution of Mechanical Engineers.

THE INSTITUTE OF MARINE ENGINEERS.

Dec. 9. "Modern Developments in Ship Design, with Special Reference to Propulsion," by Messrs. J. Tutin, D.Sc., and A. C. Hardy, B.Sc. (Assoc. member).

ELECTROPLATERS' AND DEPOSITORS' TECHNICAL SOCIETY.

Dec. 10. Joint meeting with Faraday Society:—
"The Determination of the Porosity of Electrodeposits." D. J. Macnaughton, F.Inst.P., A.I.E.E.
"The Influence of Small Amounts of Chromic Acid and of Chromium Sulphate in the Electrodeposition of Nickel." D. J. Macnaughton, F.Inst.P., A.I.E.E., and R. A. F. Hammond, B.Sc.
"'Stopping Off' Materials for Use in Electrodeposition of Nickel." D. J. Macnaughton, F.Inst.P., A.I.E.E., and A. W. Hothersall, M.Sc.
"The Electrodeposition of Cobalt Nickel Alloys." S. Glasstone and J. B. Speakman.
"The Time Factor in Anodic Passivation of Metals." W. L. Shutt and J. Stirrup.

Correspondence.

To the Editor, Metallurgia.

Dear Sir,—We are extremely interested in your article on the "Miris Process," by Mr. Edward D. Lacy, which appeared in your August issue. We would like samples of this Miris steel, to try for electric butt welding, together with a range of nickel and carbon steel.

We would also like any information the author can give regarding free sulphur, and whether this actually combines with the manganese so that no free sulphur is left in the material.—Yours, etc., J. W. P.

Old Hill,
Staffordshire.

To the Editor, Metallurgia.

Dear Sir,—With reference to your communication from J. W. P., I have been in communication with the consulting engineer to the Miris Steel Co. regarding the question of free sulphur, and whether this combines with manganese to free the matter from sulphur.

Miris steel contains no free sulphur whatever. When manganese is present to the extent of three or more times that of the sulphur—as it almost invariably is—then the whole of the sulphur is in the form of manganese sulphide. Should, however, the manganese be less than three times the sulphur present, then sulphide of iron is formed, but only to the extent of the excess sulphur.

Sulphur prints made from Miris treated and untreated ingots (from the same charge of steel) show considerably less sulphide in the Miris-treated ingots than in the untreated.

Also, the Miris treatment gives equal distribution of the sulphide, and it does not occur in patches, as in untreated steels, in which segregation always occurs—more or less—and sometimes in highly concentrated patches. Miris steel is homogeneous and uniformity can be counted upon.

Further, the manganese sulphide in Miris steel is in the ovoidal or globular form, and does not take on the mesh-like form which is the most dangerous form (as it collects between the crystals of the steel, and thereby reduces crystalline cohesion).

When sulphide of iron is formed, it is found partly in solution with the manganese sulphide. Miris treatment prevents "red-shortness" or "hot-shortness" at ordinary rolling temperature, but it has also to be borne in mind that Miris steel can be rolled at temperatures much higher than are usually employed, still with no sign of "red-shortness," thus proving our claims *re* sulphur. As sulphur is recognised as one of the elements most unequally distributed in ordinary steels, the great benefit conferred by the Miris treatment is readily apparent.

At the moment, there is no company operating this process, but Miris Steel, Ltd., will be incorporated within the course of the next few weeks, to conduct business as manufacturers of steel by this process.—Yours faithfully,

Essex. E. D. Lacy.

[Further correspondence has taken place on the subject of "Miris" steel, and we are indebted to the above correspondents for permission to publish information on a subject which will be of considerable interest to many of our readers.—Ed.]

To E. D. Lacy, Esq. October 21, 1930.

Dear Sir,—We have your very interesting letter of the 15th inst., forwarded to us by Metallurgia, for which please accept our thanks.

We are interested in steel of drop-forging quality, when made suitable for electrically butt welding. The trouble experienced at present in our bought forgings is "red-shortness," and we wondered if it was possible to overcome this by the "Miris" process, enabling us to use the cheaper steel, which could be treated and made weldable.

When we purchase large quantities of bar steel we continually get trouble due to segregation of the sulphides. Is the Miris process one that is not too costly, and such that we could instal ourselves, which would enable us to buy cheap material and treat it to make it of good welding quality?

Further, we have to make up quantities of weldable articles in higher carbon steels up to 0·6% carbon contents. Does this process have a similar effect on this quality steel? If you consider the process suitable for our purpose, we are prepared to make use of the treatment, provided it helps in increasing the weldability of the steel.

We await your remarks with interest.—Yours faithfully

Old Hill, J. W. P.
Staffordshire.

To Messrs J.W.P.
Old Hill
Staffordshire. October 28, 1930.

Dear Sirs,—I regret that I have not answered your letter of the 21st inst. before, as I have been in communication with the consulting engineer relating to Miris steel, and I now have pleasure in giving his answer to your question hereunder.

"We are pleased to hear you are interested in steel for drop forgings, as Miris steel has proved itself to be pre-eminent for this class of work, and for electrical butt welding. Certain tests were carried out on drop forgings (tested to destruction), after the forgings themselves had been treated by the Miris process and gave results 50% better than were obtained on drop forgings made from the same charge of steel which had not been treated.

"However, we much prefer to treat the steel in the ingot stage, as the maximum advantages are then obtained, and the relative cost per forging from Miris steel, as compared with ordinary steel, is so little more that the slight extra initial cost is almost negligible, and when the advantages are considered Miris treatment undoubtedly leads to a great saving in the end.

"We note that, like other users of bar steel, you continuously get trouble from segregation, and the loss of material and time due to this cause aggregates many times the slight extra cost of bars produced from ingots treated by the Miris process, so that in the end Miris steel is not only considerably cheaper, but the superior quality is there.

"It is not our intention to license out the process, but to supply finished material (Miris treated), whose welding qualities are admittedly unsurpassed.

"For deep-pressing qualities Miris steel stands alone, and there are instances on record of Miris steel standing deep-pressing tests when every other steel supplied for that particular purpose had failed. We would also point out that in a special requirement of 60-ton steel to a specification taken from a sample of German steel, again Miris steel was, firstly, the only steel which fulfilled the terms of the specification, and, secondly, stood up to the pressing tests required.

"Miris steel of 0·6 carbon can be pressed and readily welded. From the same charge we have pressed motor-car frames as easily as ordinary mild steel, and supplied rolled bars which were made into Whitworth taps for use in the Pearn's Lightning Tapper with complete success, and without a single failure. This was a test carried out on many tons of material.

"Miris 0·6 steel is easily welded. The process has been applied to steels containing as high as 1·2 carbon. In conclusion, it can be safely taken that steel treated by the Miris process is more readily weldable, whatever the carbon content, than steel untreated by the process."

If there is any further information that I can give you, I should be only too pleased to hear from you in due course.
—Yours faithfully,

Essex. E. Dacre Lacy.

*The Problem of Machinability—Measurement

By Edward G. Herbert, B.Sc., M.I.Mech.E.

PART III.

Law of Machinability—The Hardness of the Chip as a Measure.

IT has already been explained why the hardness or tensile strength of a metal can give no certain indication of its machinability, and why the order of machinability of a series of metals under a given set of cutting conditions may be entirely changed by altering the conditions. A comparison of the results of chip analysis of a wide selection of ferrous metals, comprising wrought iron, high tensile steels, free-cutting steels, manganese steel, cast iron, stainless steels, and a variety of the more usual alloy steels has led to the conclusion that there is only one possible index to the machinability of metals, namely, the hardness of the chip, and this has been put forward as the general Law of Machinability. "The Measure of Machinability is the Hardness of the Chip." It takes account of the capacity of the metal to be work-hardened by deformation and of the degree of deformation actually caused by any given set of cutting conditions, including that most important and most elusive condition, the form and the efficiency as a cutting implement of the built-up edge on the tool.

The work-hardening of the metal by the cutting tool has been shown to exercise a most important influence on the resistance offered to the operation of cutting. Recent research has brought to light another unsuspected factor in the machining of metals—namely, the work-hardening or super-hardening of the tool by the abrasion of the chip. Investigation of the upper surface of tools which have been worn in cutting has revealed the fact that the worn area where the chip impinges, some little distance behind the built-up edge, is in some cases much harder than any other part of the tool. This super-hardening is believed to exercise an important influence on the resistance of the tool to wear, and therefore on its durability in cutting.

The presence of certain alloying elements such as nickel, chromium, and manganese, in structural steels, has been shown to impart an abnormally high capacity for work-hardening, with the result that steels containing a high percentage of these elements are found to offer a resistance to the cutting tool quite out of proportion to their original hardness or their tensile strength. Recent developments in tool steels have, however, pointed the direction towards the machining of even the most refractory alloy steels with comparative ease. The introduction of the intensely hard, though brittle, bodies formed from tungsten carbides embedded in a softer matrix has been a step in this direction, but side by side with this advance has gone a development of tool steels which seems likely to lead to a solution of many machining problems, without the necessity of introducing the undesirable features of fragility and high cost which are characteristic of the tungsten carbides.

The introduction particularly of cobalt into high-speed steels, has been found to impart to the hardened steel a quite abnormally high capacity for superhardening, which is merely work-hardening on a higher plane of hardness, with the result that tools possessing these characteristics have been found capable of cutting metals whose hardness approaches, or even exceeds, that of the tool itself. The process involved may be described as one of mutual work-hardening. The tool deforms the work, and induces a high degree of hardness in the whole region of the cut, but especially in the chip. The hardened chip passing under heavy pressure across the top surface of the tool, super-hardens it, producing a relatively thin but intensely hard skin, capable of resisting abrasion of such severity as would immediately destroy a tool not possessing the high superhardening characteristic.

There is reason to believe that this effect is attained in its fullest extent only when cutting metals which are intrinsically hard, such as chilled cast iron, or which have a

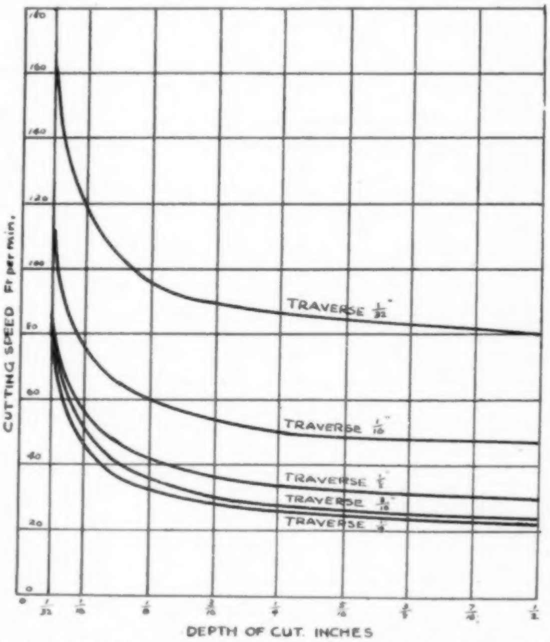


Fig. 8.—Variation in Cutting Speed with Change in Depth of Cut and Traverse when Cutting Mild Steel (34 Tons T.S.).

very high work-hardening capacity, such as manganese steel. It has, however, been found possible to superharden the upper face of the tool by artificial means, thus imparting to it a high degree of resistance to abrasion, and a greatly increased durability in cutting metals of less abnormal character.

As an instance of what has already been accomplished in this direction, it may be mentioned that a certain cobalt tool steel was found capable of being super-hardened up to a diamond time hardness (measured with the pendulum) of 113·1, equivalent by conversion to 1525 Brinell, while the high durability of tools made of this steel was increased no less than 84% by previously superhardening their top faces, the work material being in this case a 50-ton steel containing 1% carbon and 1% chromium. Such results seem likely to lead to quite new standards in the machinability of metals.

The subject of machinability has hitherto been considered in relation to the widest possible range of ferrous metals, including those so dissimilar in character as cast iron, high tensile alloy steels, and manganese steel, and it has been shown that no general quantitative relationship

*Continued from page 208 in October Issue.

exists or can exist between their tensile strength or hardness and their resistance to machining. It has, however, been found possible to divide these very diverse materials into classes or categories, and by excluding the more

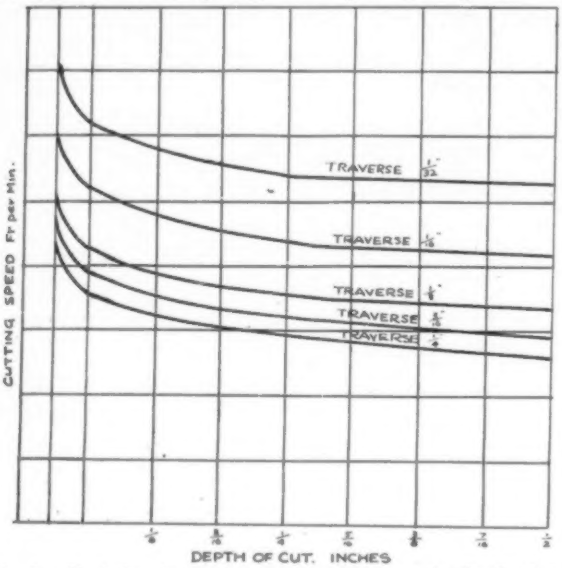


Fig. 9.—Variation in Cutting Speed with Change in Depth of Cut and Traverse when Cutting Cast Iron.

abnormal metals altogether from review, to establish certain approximate relationships applicable to restricted classes of metals.

Thus Boston says (" Research in the Elements of Metal Cutting," A.S.M.E. 1926) : " For certain physical properties the materials divide themselves into three groups —namely, straight carbon steels, alloy steels, and cast iron, for each of which a relation is indicated. For the straight carbon steels it appears that the elastic limit in tension and compression, the ultimate strength in tension and shear, and the Brinell hardness, are functions of the unit force on the tool. For the alloy steels the elastic limit in tension and compression, the ultimate strength in tension compression and shear, the Brinell hardness, and the percentage of elongation in two inches, each indicates a relation to the unit force. For cast iron a similar relation is suggested for the ultimate strength in tension, compression, and shear, and the scleroscope hardness number."

We have here an indication of the kind of classification which may be turned to account. It will be observed that this investigator correlates the physical characteristics of the metals with the " unit force on the (planer) tool," which is only one, and not, perhaps, the most generally useful, measure of machinability. Moreover, the dividing line between " straight carbon steels " and " alloy steels " is somewhat indefinite, since most of the carbon steels contain a proportion of the alloying elements, and it is doubtful whether " alloy steels"—that is, steels which contain a relatively high proportion of the alloying elements—can be safely treated as a single class, unless by way of excluding them altogether as regards any definite relationship between their machinability and physical characteristics. Subject, however, to these limitations, the classification is a useful one.

[Since the commencement of these articles, Mr. Herbert has received a communication from Professor Boston, in which he states that his former conclusions as to the grouping of metals are found to be no longer valid when the cutting conditions are modified by the introduction of various cutting oils. EDITOR.]

Professor Dempster Smith has adopted a somewhat similar classification, but has correlated the physical characteristics of the various metals with their machinability as measured by the cutting speed, which would be expected to give a life of two hours to a tool of high-speed steel of good quality. He has excluded the " alloy steels " altogether, but has correlated the machinability of the " straight carbon steels " and the cast irons with their Brinell hardness and tensile strength. Figs. 8 and 9 give the cutting speeds for a two-hour tool life on a mild steel of 34 tons tensile strength and a cast iron of Brinell hardness 143, respectively, with various combinations of depth of cut and traverse. Dempster Smith says: " There is no close relation between the cutting speed and the strength of all metals ; but for straight carbon steels (*i.e.*, containing little or no nickel, manganese, chromium, or tungsten) there is an approximate relationship which falls within the limits of ordinary workshop practice." The cutting speeds on mild steel, Fig. 8, are to be multiplied by the " speed factors " in the following table to render them applicable to straight carbon steels of different strength and hardness :—

CUTTING SPEED FACTORS FOR DIFFERENT STEELS.

Tensile strength—tons per sq. in	25	30	34	38	44	48	53
Brinell hardness No.	120	140	160	176	200	220	240
Speed factor......	1·54	1·28	1·0	0·833	0·67	0·57	0·51

Similarly, the cutting speed factors for cast iron, and applicable to the speeds in Fig. 9, are given as follows :—

CUTTING SPEED FACTORS FOR SEVERAL CAST IRONS.

Brinell hardness No.	187 ..	166 ..	149 ..	143
Speed factor...........	0·44 ..	0·77 ..	0·60 ..	1·00

The figures refer to a tool $1\frac{1}{4}$ in. square, having a plan angle 60° and nose radius $\frac{1}{8}$ in., cutting without coolant, and it is stated that the use of a cooling medium would permit of speeds about 15% higher.

In a recently published work by Wallichs and Dabringhaus (" Die Zerspanbarkeit und die Festigkeitseigenschaften bei Stahl und Stahlguss," A. Wallichs and H. Dabringhaus, " Der Betrieb," V.D.I., April 17, 1930) the authors claim

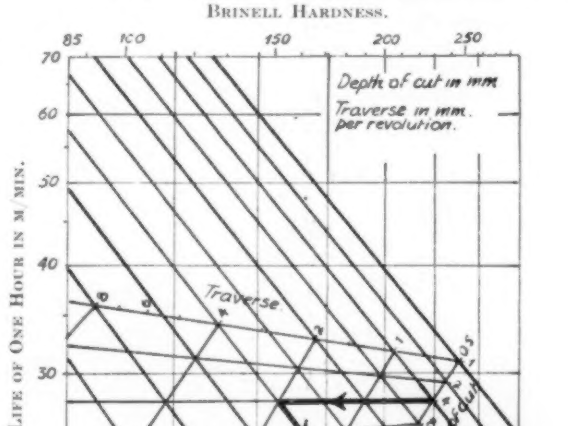


Fig. 10.—Machining Diagram for Turning of Steel and Steel Castings for a High-speed Steel Tool with 30° Plan Angle, Cutting Dry.

to have found a practically consistent relationship between machinability, measured by the cutting speed for a tool life of one hour, and the Brinell hardness and tensile

strength of a much wider range of steels, including not only straight carbon steels, but also many alloy steels, among which the compositions in Table I. occur.

The authors publish the "Nomogram" Fig. 10, giving the relationships between cutting speeds for a tool life of one hour at various feeds and depths of cut, and the tensile strength and Brinell hardness of the steels.

TABLE I.

Symbol.	C.	Si.	Mn.	P.	S.	Cr.	Ni.	Cu.
EN 15_1	0·12	0·31	0·42	0·005	—	0·13	1·84	—
Stg 5081	0·32	0·52	0·69	0·030	0·008	—	0·01	0·124
Stg 5081	0·21	0·33	0·52	0·025	0·017	0·67	1·61	0·141
ECN 35	0·15	0·31	0·51	0·015	—	0·71	3·44	—
ECN 35_2	0·12	0·32	0·48	0·015	—	0·81	3·58	—

In the course of correspondence, Professor Wallichs points out that these relationships apply *only to heavy cuts*, that they do not apply to "free-cutting steels" containing high phosphorus and sulphur, nor to cast iron, but that they can be applied to all plain carbon steels up to 0·6% carbon, to all normally alloyed steels as used in automobile work, and to all usual classes of steel castings, excluding special metals such as manganese steel and steels containing a high percentage of chromium and nickel.

It would be desirable to define more exactly the limiting percentages of alloying elements within which the relationship exists, but apparently further work is going forward, and it will be seen that the claim for a physical basis of machinability is a broad one, going far beyond what has been put forward by British and American investigators.

The method of using the nomogram has been indicated by thick lines, and is as follows:

To find the cutting speed for a tool life of one hour with a traverse of 2 mm. and a depth of cut 4 mm. on a steel whose Brinell hardness is 170 (tensile 60 kg./mm.²): find the desired depth of cut, 4 mm., and follow the nearly horizontal line until it meets the line for traverse 2 mm. sloping down from right to left. From the intersection, follow the "principal" diagonal line sloping down from left to right until it cuts the vertical line corresponding to the Brinell hardness 170 and tensile strength 60. A horizontal line through the point of intersection will cut the vertical scale of cutting speeds at 23·5 metres per minute, say 77 ft. per minute, which is the speed required.

(Concluded)

High-Test Cast Iron

The Rocking Type of Electric Furnace is claimed to have opened a new field for producing uniformly good high-test cast iron without the use of expensive alloying elements.

A round-table discussion on the application of the Detroit rocking electric furnace to the production of high-duty grey iron, took place at one of the sessions of the Electrochemists' Convention recently held at Detroit, with Dr. Richard Moldenke in the chair. Carl H. Morken referred to the work of Lanz, Corsalli, Deschene, and others in establishing new schools of thought in the production of grey iron castings. The Lanz Pearlit, the Thyssen Emmel, and the Corsalli processes were developed and used to produce high quality iron from the cupola. While these processes are metallurgically successful, the procedure required is involved, and uncertainty exists in obtaining the desired results, due largely to the uncontrollable nature of the cupola. The rocking type of electric furnace, he asserted, has opened a new field in producing uniformly good high-test grey iron without the use of expensive alloying elements. Its use has enabled foundrymen to produce readily machinable castings possessing an ultimate tensile strength of 50,000 lb. per sq. in. or more, and in determining in advance just what type of iron is desired without the necessity of highly trained metallurgical attendance.

TABLE I.
PROPERTIES OF IRON MADE FROM BORINGS.
Charge: Iron borings, 80%; steel scrap, 20%. Pouring temperature: 3,100° F. (1,704° C.). Test bar: A.S.T.M., 0·25 in. (6·35 mm.) arbitration bar.

	No. 1.	No. 2.
Total carbon, %	2·78	2·74
Silicon, %	2·15	2·18
Sulphur, %	0·061	0·059
Phosphorous, %	0·154	0·167
Manganese, %	0·76	0·76
Nickel, per cent.	0·82	1·80
U. T. S., lb. per sq. in.	48,360	46,380
U. T. S., kg. per sq. cm.	3,400	3,261
Transverse, lb.	7,630	7,200
Transverse, kg.	3,461	3,266

NOTE.—The nickel showing in No. 1 was incidental and not added. It probably came from the iron borings used, which were not analysed.

This rocking furnace is of the indirect arc type, and employs both radiation and conduction in the heat transfer. It may be considered as a horizontal drum set upon a suitable base, with the electrodes entering at the axes. Since it operates single-phase, only two electrodes are used. In operation, the furnace rocks about its approximate horizontal axis, first clockwise, then anti-clockwise. The arc of rotation in either direction is limited only by the relationship of the metal line to the door opening. The rocking is controlled by mechanical means, and the direction of rotation is reversed automatically at predetermined points, which are adjustable. Thus, the degree of rock can be varied, as desired, from minimum to maximum angle.

Production Method and Data.

This furnace utilises three principal methods for the production of high-test grey iron: Straight cold melting of various charges; duplexing cupola iron; or the triplexing process. In all three processes, either bath or continuous methods are used. In the bath method the furnace is emptied with each heat, and a complete new charge is supplied to the empty furnace. In continuous production the furnace is not emptied until at the end of the day. Each time a ladle of metal is removed from the furnace an equivalent amount of the required charge is added, maintaining the furnace at maximum capacity at all times.

TABLE II.
COST OF MELTING BORINGS.

	Cost per Ton.
Power, 540 k.w.-hr.	\$6·75
Electrodes	1·60
Refractories	1·50
Labour	1·00
Conversion cost per ton charged	\$10·85
Value of borings (average)	7·00
Total cost per ton charged	\$17·85
Recovery, 97%.	
Total cost per ton poured	\$18·40

Straight Cold Melting.—The use of iron borings, without briquetting, is of great economic importance, and they afford the opportunity of producing high-test iron at costs below those of cupola operation. The properties and cost of producing high-quality iron is shown in Tables I. and II.

Cheap steel scrap is frequently available, and can be converted into high-test grey iron at a low cost. The steel scrap is melted, brought to the desired composition by additions of ferro alloys and petroleum coke, and the bath superheated. The analysis can be controlled within close limits, and the resultant synthetic grey iron is of an

exceptionally high quality. Table III. illustrates the properties of synthetic grey iron made from steel scrap in this furnace, while Table IV. gives the cost of producing the same iron. The efficiency of recarburising is clearly illustrated in Table V.

Duplexing Cupola Iron.—In this process the charge is melted in the cupola and transferred to the electric furnace for further treatment, which consists of superheating the metal from 149° to 204° C. above the cupola temperature, and holding it at this temperature (approximately 1,649° C.) until the carbon is in complete solution. The furnace is kept on continuous rock during the entire process, thus refining and deoxidising the bath.

TABLE III.

PROPERTIES OF SYNTHETIC GREY IRON.

Heat No.	Total Carbon.	Silicon.	Brinell.	Ultimate Tensile Strength.	
				Lb./sq. in.	Kg./sq. cm.
2-B	3·05	2·96	228	34,000	2,390
111	3·20	2·98	235	34,600	2,432
1	3·60	3·56	228	24,000	1,687

TABLE IV.

COST OF SYNTHETIC GREY IRON.

	Cost per Ton.
Power, 600 k.w.-hr.	$7·50
Electrodes	1·80
Refractories	1·50
Labour	1·25
Conversion cost per ton charged	$12·05
Value of steel scrap	8·00
Total cost per ton charged	$20·05
Recovery, 99%.	
Total cost per ton poured	$20·25

This process, the author states, is not widely used because of the uncontrollable nature of the cupola, particularly when attempting to produce low carbon iron. A comparatively low carbon content and an accurately controlled carbon-silicon ratio being essential for the production of high-test grey iron. Consequently, it is usually found necessary to adjust the composition of the cupola iron after it has been transferred to the electric furnace. This type of production is discussed under the triplexing process.

TABLE V.

EFFICIENCY OF RECARBURISATION.

Coke Added %	Total Carbon in Iron.	Carbon in Steel.	% Absorbed.
4·50	3·20	0·25	65·4
4·69	3·30	0·25	65·0
4·72	3·35	0·25	65·2
4·70	3·43	0·25	67·7
4·86	3·35	0·25	64·0
5·20	3·58	0·25	64·0

Table VI. illustrates the improvement obtained by duplexing cupola melted iron. The bars of the cupola metal were obtained just before the metal was poured into the electric furnace. Table VII. gives the cost of duplexing cupola iron in this type of furnace, based upon superheating the cupola metal from 180° to 220° C.

TABLE VI.

EFFECT OF DUPLEXING CUPOLA IRON.

Heat.	Total Carbon.		Total Silicon.		Total Sulphur.		Transverse Strength.	
	Cupola.	Duplexed.	Cupola.	Duplexed.	Cupola.	Duplexed.	Cupola.	Duplexed.
1	3·40	3·45	1·88	1·76	0·09	0·05	2,800	4,120
2	3·28	3·12	2·06	1·92	0·12	0·07	3,520	4,960
3	3·37	3·25	2·25	2·17	0·11	0·07	3,160	4,080

Triplexing Process.—In the production of high-test grey iron it is usually desirable to maintain the total carbon at a figure below 3·00%, frequently below 2·75%. It has been found that the most economical manner of producing iron of this composition is by the triplexing process. A definite quantity of this cupola iron is mixed, in the electric furnace, with predetermined quantities of steel scrap and ferro alloys. The bath is then raised to the proper temperature and the metal poured.

The properties of this type of iron are dependent upon the composition selected. Ferro alloys are frequently added to increase the strength of the iron. Table VIII. illustrates the properties of some representative irons obtained by triplexing cupola metal in this furnace.

TABLE VII.

COST OF DUPLEXING CUPOLA IRON.

	Cost per Ton.
Power, 100 k.w.-hr.	$1·25
Electrodes	0·35
Refractories	0·30
Labour	0·20
Total cost per ton	$2·10

TABLE VIII.

PROPERTIES OF VARIOUS TRIPLEXED IRONS.

Total C %	Si %	Ni %	Mo %	Ultimate Tensile Strength.		Tensile Strength.		Deflection.		Brinell No.
				Lb./sq. in.	Kg./sq. cm.	Lb./sq. in.	Kg./sq. cm.	In.	Mm.	
2·61	1·98	0·89	Nil	58,700	4,127	5,600	394	0·132	3·4	241
2·67	2·08	0·97	Nil	53,250	3,744	5,175	364	0·120	3·0	269
2·78	1·91	2·46	0·55	60,000	4,219	4,700	330	—	—	286
3·00	2·07	Nil	0·35	55,600	3,909	—	—	0·126	3·2	—
2·52	2·29	Nil	0·44	54,000	3,795	8,045	566	0·165	4·2	—

The cost of triplexed iron is dependent upon the composition. Obviously, the cost is lowered, and the speed of production is increased by holding at a minimum the cold metal additions in the electric furnace. They usually range from 10 to 20% of the total electric furnace charge. Tables IX. and X. illustrate the cost of triplexing two different types of charges in this furnace.

Metallurgical Control.

It has been previously pointed out that this rocking furnace operates without a slag covering on the bath, and with a non-oxidising atmosphere. The result of these conditions are low losses during melting down and superheating the metal. When the composition of the charged materials is known it is quite a simple matter to calculate a charge to produce a given result. With the charge supplied, a metallurgically inexperienced operator can produce the desired iron in routine manner.

TABLE IX.

COST OF TRIPLEXING CUPOLA IRON.

Charge: 85% molten cupola iron; 15% cold steel scrap.

	Cost per Ton.
Power, 160 k.w.-hr.	$2.00
Electrodes	0·60
Refractories	0·70
Labour	0·30
Total cost per ton	$3.60

TABLE X.

COST OF TRIPLEXING CUPOLA IRON.

Charge: 72% molten cupola iron; 20% cold iron borings; 8% cold steel scrap.

	Cost per Ton.
Power, 225 k.w.-hr.	$2·81
Electrodes	0·70
Refractories	0·80
Labour	0·40
Total cost per ton	$4·71

With the composition of the charged materials unknown, the " chill test " is employed. When the heat is thought to be ready, as judged by the watt-hour meter and the appearance of the bath, a " chill test " is made. This, in its entirety, requires approximately 2 mins. If the iron is too hard, ferro-silicon or petroleum coke, or both, are added; if too soft, steel is added, and the furnace rocked to ensure homogeneity. Seldom are more than two chill tests required, and an operator soon becomes so expert at reading the tests and judging his additions that he frequently omits the second.

Bimetal–Its Function and Application

By W. J. P. Rohn, Dr.Phil.Nat.

Definition—Principle of bimetal strips—Coefficient of thermal expansion of metals and alloys—Discussion of points of view for selecting the components.

BIMETAL is a name employed by physicists and engineers to designate strips made from two metallic layers with different coefficients of thermal expansion. The strips curve in one direction or the other with the increase or decrease of temperature. The two metallic layers may be united by riveting, soldering, or best by welding. In the old text-books of physics, thermometers are described consisting of a bimetal strip wound in a flat spring or helical spiral, one end of the strip being fixed and the other end carrying a pointer, the position of which indicates the temperature. During recent years bimetal strips or discs have been employed to an increasing extent in the electrical industry and in the construction of simple and cheap apparatus designed for operating at a predetermined temperature or for continuously controlling temperatures.

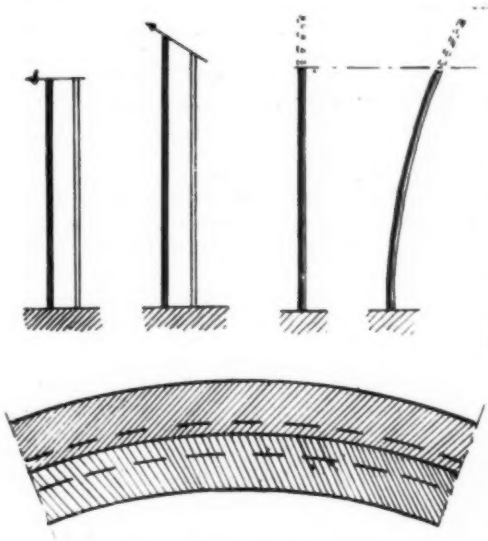


Fig. 1.—Principles of Bimetal Strips.

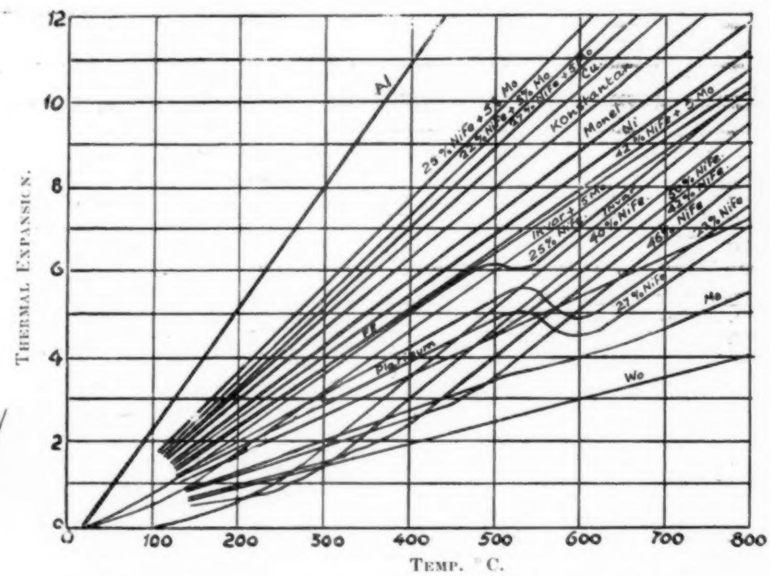


Fig. 2.—Coefficients of Expansion of Various Metals and Alloys.

In these two instances the use of the bimetal is fundamentally different. In the first case it must operate only at a single determined adjustable temperature, its behaviour at higher or lower temperatures being of no consequence in this instance. In the second case it must serve as a measuring instrument for the widest possible temperature range, and the continuous alteration in its characteristics should be as uniform as possible between these temperature limits. The author discussed these considerations in an article which appeared in *Zeitschrift für Metallkunde*, August, 1929. Later on it will be seen how the choice of the components of the bimetal, its manufacture, and applications depend upon these two considerations.

The function of a bimetal is based upon the difference in the coefficients of expansion of its two constituents, and, in order to select a suitable combination of metals, consideration must be given to the different coefficients of expansion of various metals and alloys and to the variation of these coefficients with temperature.

It will be observed from Fig. 2 that the metals having the lowest coefficients of expansion do not have straight lines for their expansion curves, but that these curves are divided into a slightly inclined part at lower temperatures and a steeper part at higher temperatures. The change from a low to a high coefficient of expansion takes place at different temperatures, so that the element having the low coefficient of expansion must be suitably selected, depending upon the required working temperatures. If the temperature range over which the bimetal strip is to work lies between room temperature and 120° C. maximum, a nickel-iron alloy (35% nickel), known as "Invar," is used, preferably, as the component with a low coefficient of expansion. Up to 230° C. a 40% nickel-iron alloy, up to 340° C. a 42%, and up to 440° C. a 46% nickel-iron alloy are most advantageous. Above these temperature limits the coefficients of expansion of the above-mentioned alloys increase so rapidly that the difference in expansion between the bimetal components rapidly decreases. Each of the bimetal combinations with one of the above-mentioned nickel-iron alloys can be used only within its corresponding temperature limits, because outside this range the curvature becomes so slight as to be no longer useful.

As the component with the high coefficient of expansion, it might be anticipated from a glance at Fig. 2, that aluminium would find a useful application, but there are, however, two serious disadvantages which militate against its use. Aluminium does not lend itself easily to soldering or welding with other metals. Again, aluminium has relatively poor tensile properties as compared with the nickel-iron alloys used as the components with low expansion coefficients. This leads to an important consideration in the manufacture of bimetal.

On examining Fig. 1, which depicts an enlarged cross-section of a bimetal curved by rise in temperature, it will readily be appreciated that the component with the higher coefficient of expansion is in tension on the outside and in compression on the inside. The opposite is true of the component with the lower coefficient of expansion. This is in compression on the lower side and in tension on the

side where it adjoins the other component. The neutral layers should theoretically have a distance apart equal to two-thirds of the total thickness of the bimetal. This, however, can only be attained if both components have identical tensile and elastic properties. In practice, however, there is considerable deviation from this theoretical

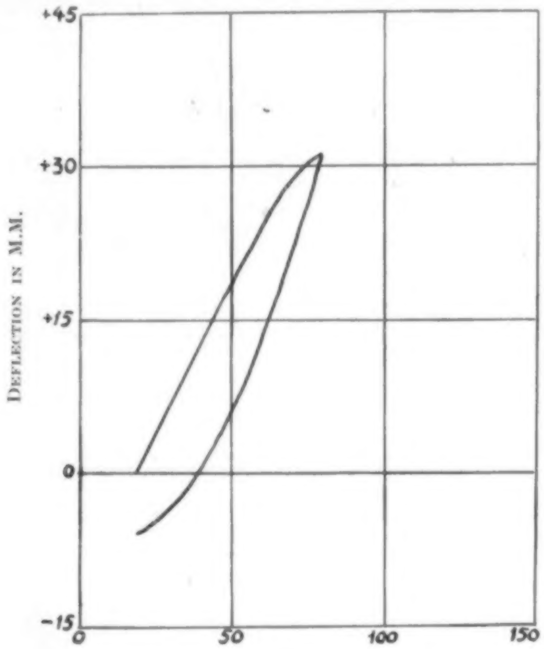


Fig. 3.—Deflection Curves for a Bimetal Invar-Lead on Heating and Cooling.

condition. It is obvious that in the immediate neighbourhood of the junction of the two components there must be, at least in a small zone, a certain overstepping of the elastic limits of the materials during heating and cooling. Such deformations beyond the elastic limits are not completely reversible with temperature, so that the bimetal strip does not in this case regain its original shape on cooling.

Although the above considerations have made it evident that a bimetal consisting of a hard and soft metal will most probably be unsatisfactory, yet these considerations are only of an approximate nature. These phenomena are hardly conducive to mathematical treatment, and it is better to test these conclusions by experiment. A bimetal was therefore made, one component being Invar and the other lead, the thickness of each layer being 1 mm. A strip of this bimetal was given the following treatment: Heated from room temperature to 80° C. and cooled, reheated to 110° C. and again cooled to room temperature, and finally heated to 130° C. and further cooled to room temperature. The results obtained are indicated in Figs. 3, 4, and 5, in which the temperatures are abscissa and the ordinates are the curvatures of the free end of a lead-Invar strip, 100 mm. × 10 mm. wide. The time of each cycle was from 15 to 20 mins. for heating and 40 to 60 mins. for cooling.

Fig. 3 shows a rectilinear rise of curvature to 65° C. Above this temperature, the increase of curvature per degree of temperature rise. becomes increasingly smaller. On cooling, a completely different curve was followed, and the original zero was displaced by 40° C. After complete cooling there remained a negative change of the zero point of about 10° C.

In Fig. 4, in which the strip was heated to 110° C., the first noticeable change in the proportional increase in curvature appears at 75° C. On decreasing the temperature, the original zero was passed at 65° C.

In Fig. 5, in which the heating was to 130° C., the first noticeable departure from a linear course appeared at about 75° C., and the original zero was passed at 55° C.

Although lead is an especially soft metal, these results bring out forcibly the futility of making a bimetal of two components whose hardness and elasticity differ widely. When used in conjunction with nickel-iron alloys, copper is much too soft to form a useful bimetal. This explains what was already a well-known fact in practice—namely, that a bimetal of Invar and copper will not give a reliable reproduction of the zero point if used over a rather considerable temperature range.

Such a bimetal would be unsuitable for all purposes which require accurate working conditions. It is of greatest importance, therefore, to combine only components with the same strength, and, if possible, of equal and great elasticity. Therefore a nickel-iron alloy containing between 35% and 46% nickel is used as the component with a low coefficient of expansion, and for the component with the high coefficient of expansion, either Constantan (45% nickel, 55% copper) or Monel metal (65% nickel, 30% copper, 5% iron, 4% manganese). Such bimetal combinations have proved to be entirely satisfactory. The only disadvantage is that the waste material produced from their manufacture contains three metals—namely, iron, nickel and copper,—which has only a low scrap value, and has to be subjected to chemical separation before it can be used for making up further alloys. For this reason a nickel-iron alloy with 22—27% nickel has found favour as the high expansion component, this combination yielding an excellent bimetal. There is, however, a certain element of danger in the use of these latter nickel-iron alloys, and care has to be taken to avoid possible errors creeping in. From Fig. 2 it will be observed that nickel-iron alloys with 22—27% nickel exhibit transformation points, and therefore a strongly marked change in their coefficient of expansion curves, and the coefficients of expansion will depend upon the rate of cooling from temperatures between 600° C. and 800° C. to room temperature.

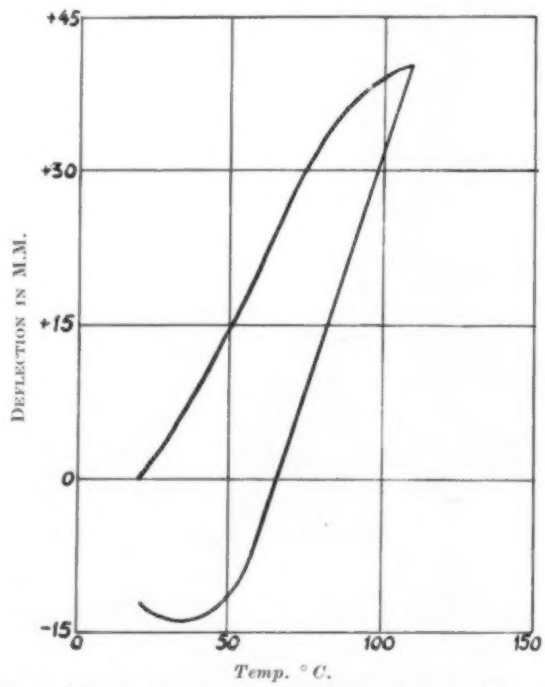


Fig. 4.—Deflection Curves for a Bimetal Invar-Lead on Heating and Cooling.

In the manufacture of bimetal, it must be first hot-rolled, and, later on, annealed between the passes of the cold-rolling operation. For this reason bimetal combinations made from nickel-iron alloys with a nickel content

between 22% and 27% nickel show a certain instability. An important development in this connection was the discovery that the addition of 5% of molybdenum entirely removes this irregularity in the expansion characteristics of these alloys. These alloys no longer exhibit susceptibility to the effects of varying heat-treatments. At the same time, it appears that these nickel-iron alloys containing molybdenum have an especially high coefficient of expansion which so far exceeds that of copper that these metals appear to be peculiarly fitted for the manufacture of bimetals.

Fig. 6 shows the varying curvature, with change of temperature for a large number of bimetal combinations. These combinations, which are most important from a technical standpoint, are shown by the continuous lines, while those which are less suited for practical purposes are clearly shown by the dotted lines. Each deflection curve is shown by a continuous line only up to the temperature at which the specific combination is technically applicable. As already explained in the discussion on nickel-iron alloys containing from 35—46% nickel, Invar has a negligibly small coefficient of expansion only up to about 120—150° C. All combinations with Invar, therefore, show an approximately linear and steep deflection curve only up to these temperatures, while above these temperatures the deflection gradually diminishes. This is experienced in such combinations as Invar-Constantan, Invar-nickel, and Invar with nickel-iron alloy containing 27% nickel + 5% Mo., and these are the most important from a practical standpoint. The useful working limits of these combinations extend up to 150°—180° C. For higher temperatures a nickel steel containing 42% nickel is selected as the low expansion component. Such bimetals can be used with advantage up to 350—400° C. The combinations which find use in this instance are a 42% nickel-steel with nickel, with Constantan, and with 27% nickel-iron + 5% Mo. The last-mentioned bimetal can be used up to 550° C. Above this temperature no bimetal is suitable,

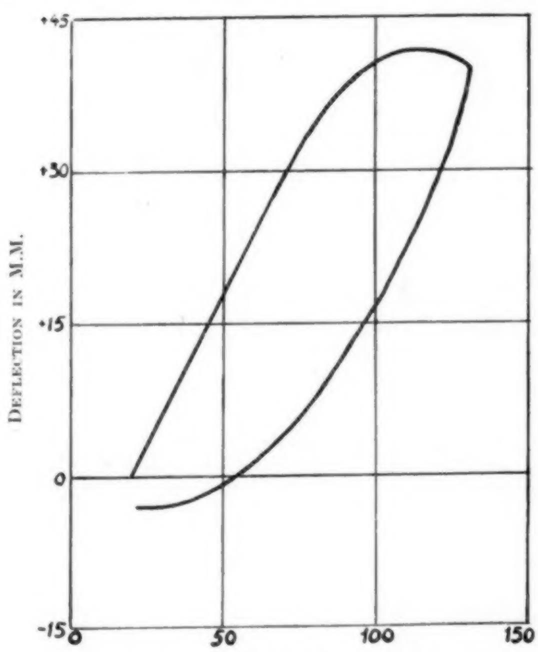


Fig. 5.—Deflection Curves for a Bimetal Invar-Lead on Heating and Cooling.

because all alloys which are used in this connection lose so much of their strength above this temperature that the zone of permanent deformation in the vicinity of the adjoining surfaces becomes wide, and therefore the zero point is no longer exactly reproduced on cooling.

All these bimetal combinations show, at least within a considerable temperature range, an approximately linear relationship between the curvature and the temperature, and are therefore fitted both for use in indicating instruments where an approximately linear scale is desirable, and for controlling any particular working temperature with considerable accuracy. If it is only needed for controlling a special working temperature, a bimetal will be chosen which has no deflection up to 20° C. below the desired working temperature, and no further deflection 20° C. above this temperature.

It will readily be appreciated that for many purposes such a behaviour represents the ideal bimetal, because in this case the deformation beyond the elastic limit in the

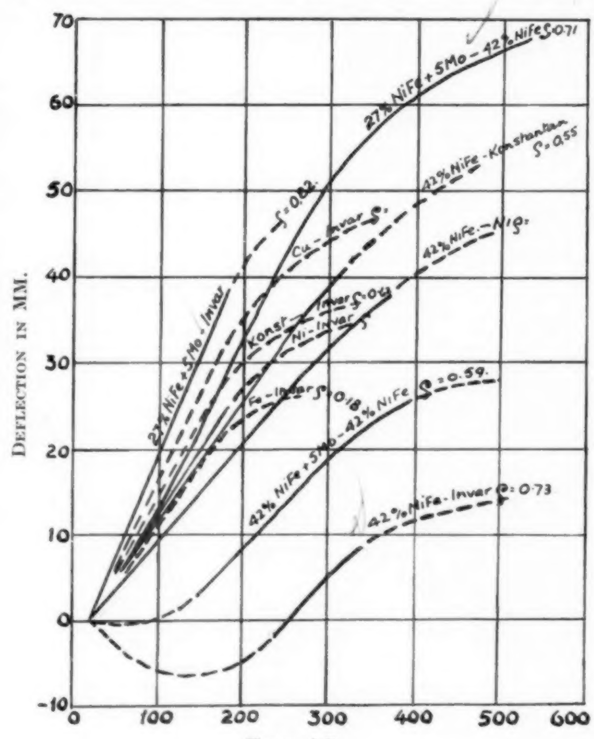


Fig. 6.—Test Strips: 100 × 10 × 0.6 mm. Both Components of Equal Thickness.

neighbourhood of the adjoining surfaces between the two components must remain especially small. Furthermore, such combinations are possible as the two curves of Fig. 6 show—namely, the combination of 42% nickel-iron with 42% nickel-iron + 5% Mo., and the combination of 42% nickel-iron with Invar. The first of these two combinations gives up to 100° C. practically no curvature, has between 150° C. and 300° C., its most useful working range, while its curvature above 400° C. shows practically no increase. The second combination is at the outset strongly negative to curvature up to 250° C., then at 250° C. the zero point is reached again, its working range proper lying between this and 350° C. Both these latter combinations bring out clearly that for a fixed working temperature the most useful combination is not the one which has the greatest total curvature up to this temperature, but one which possesses the greatest change of curvature in the immediate neighbourhood of this point. Therefore, in selecting a combination of metals, the bimetal is chosen which shows the steepest tangent when the curvature is represented as ordinate and the temperature is abscissa, and not the bimetal which has the greatest total curvature up to the operating temperature. For example, at 200° C. the bimetal composed of 42% nickel-iron and 27% nickel-iron + 5% Mo. is considerably better than the bimetal made from Invar and 27% nickel-iron + 5% Mo.

(*Continued on page 25.*)

Iron and Steel Foundry Practice

By Ben Shaw

Part VI.

Types of Equipment Used in Steel Melting.

ALTHOUGH the crucible furnace is the oldest melting appliance for providing steel of suitable temperature for casting, its use in the steel foundry is not now so common as formerly. Three types of equipment are more generally used for this purpose, which include converters, open-hearth furnaces, and electric furnaces. Each process of steel production imparts particular characteristics to the steel, and chemical compositions invariably differ slightly, sufficient frequently to indicate

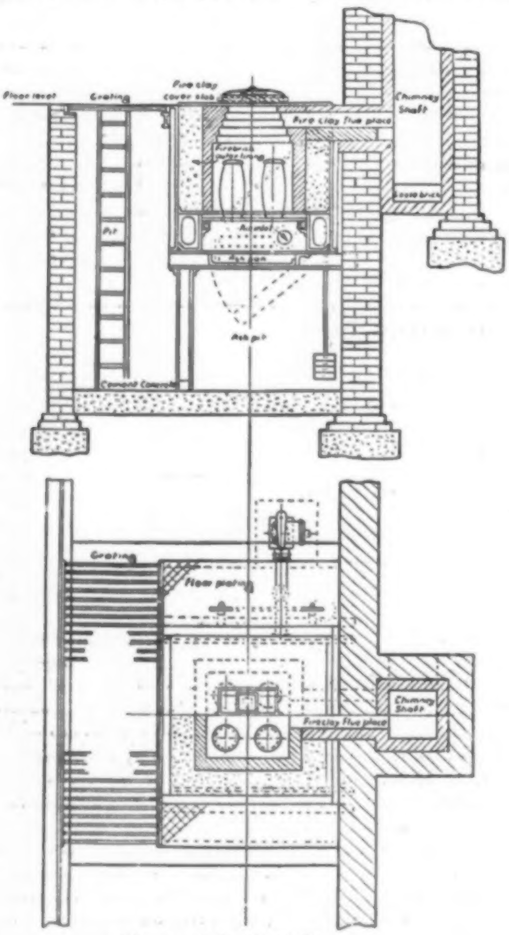


Fig. 1.—Coke-Fired Furnace.

the process by which they have been made. Each process has its advantages and disadvantages, and the installation of any one type is dependent upon many factors inseparable from economic production. Thus, the quantity of fluid metal required, the speed at which it can be prepared ready for casting, operating cost, as well as the quality of metal, are important factors, and it would be difficult to state, without considerable qualification, which process is the best under all circumstances. Crucible steel, for instance, has a high production cost, but the quality is high, and for certain classes of small alloy steel castings it is still used. Generally, it can be assumed that for small work of high quality, involving alloy steels, either the crucible or electric furnace would be used. For medium-sized steel castings the conversion of iron melted in the cupola can be done speedily and economically, and in this instance the converter is suitable, but the electric furnace is a very convenient melting unit for this purpose. The open-hearth furnace is more economical for dealing with the quantity of metal necessary for large castings.

Crucible Furnaces.

In the crucible process heating is usually accomplished by the use of coke or gas, the latter being generally preferable: thus two kinds of furnaces are involved. The coke-fired furnace has the advantage of occupying less space, but it is not as economical as the gas-fired furnace. It is, however, an independent unit, and each furnace is designed to carry two crucibles at one firing, as in Fig. 1. These furnaces are usually arranged in batteries with a common flue, similar to the pit type of furnace in use in many brass foundries. Gas-fired furnaces are usually designed on the regenerative principle, as shown in Fig. 2, which gives it an economic advantage when a continuous supply of metal is required.

The crucibles used with these furnaces are either of clay or graphite. Many melting shops make their own crucibles. After much experimental work in determining a suitable mixture of clays for crucible, firms adhere to a composition which gives the best service. Usually, a small quantity of either coke or coal dust is added. A common mixture employed for this purpose consists of 80 to 90 parts of fireclay, two parts of ground hard coke, and the remainder, to make 100 parts, of old crucibles broken and ground. On the other hand, some foundries prefer to use a mixture composed of Derby, Glenboig, and china clays in the proportion of two of Derby to one of each other of the other clays. To this mixture a small percentage of coke dust or charcoal is added. Clay crucibles cause the metal to absorb a small percentage of silicon, and while this can be obviated by the addition of a small quantity of iron oxide in the charge, it is not advisable. Graphite crucibles last longer, but the metal absorbs a small percentage of carbon, and as a preventative they are frequently lined with clay.

Crucible melted steel is only of superior quality when the furnace is properly manipulated and the charges are made up to requirements, and while it is still used for some high-grade work, it is costly to produce, and for this reason it is being gradually replaced by the electric furnace. The superiority of the steel produced by the crucible process over that from the converter and open-hearth processes is due to the fact that melting is done in a reducing rather than an oxidising atmosphere, but high-grade materials are invariably used, and this has an influence in producing a high-grade steel.

From a chemical point of view, the process is simple. The charge necessarily depends upon the amount of carbon desired in the steel. For ordinary carbon steels the charge is usually made up of wrought iron and steel scrap, with the addition of some hematite or Swedish pig, refined pig iron, charcoal in varying proportions. When alloy steels are required, ferro-alloys carrying the alloying constituents are added in the desired proportion. Since there is practically no loss of alloying element, calculation of the charge is comparatively easy. In coke-fired furnaces beehive coke is more commonly used in order to reduce the injurious

effect of solid fuel on the crucibles. The furnace must be kept well coked, to maintain a high temperature.

The time of melting in crucible furnaces varies from $2\frac{1}{2}$ to $3\frac{1}{2}$ hours. Determining when the metal has reached a suitable casting temperature is not easy; this may be gauged with the aid of an optical pyrometer, but a common method is to insert a previously heated iron rod into

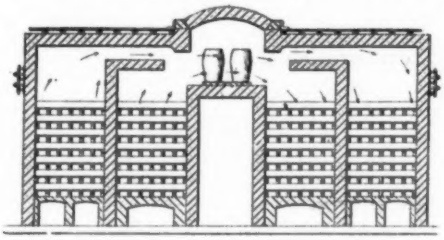


Fig. 2.—Gas-Fired Furnace.

the metal; if it comes out quite clean the metal is satisfactory. Without the iron rod, however, the experienced furnace man can judge very accurately by the appearance of the metal whether or not it is at casting temperature. It is necessary to "kill" the metal before pouring it, because during the process of melting, gases are generated which are taken up by the metal. These gases must be driven off, or rendered harmless. For this purpose the metal is kept at a steady temperature for about half an hour after it has reached a casting temperature, and to facilitate the process, it is usual to throw a very small piece of aluminium, ferro-silicon, and ferro-manganese into the metal. The action resulting from such an addition increases the solubility of the gases and checks the reduction of silicon from both crucible and slag. It has to be remembered that non-metallic inclusions weaken steel, and aluminium tends to remain there as alumina, consequently it has to be used sparingly.

Converters.

In the converter process cast iron is decarburised by blowing air through or against the surface of the molten metal. Usually, the metal is first melted in a cupola and transferred to the converter for conversion. In some instances, notably the Stock converter, Fig. 3, the melting is done in the converter; these are, however, exceptions to the usual method. The cupola is charged with pig-iron, with

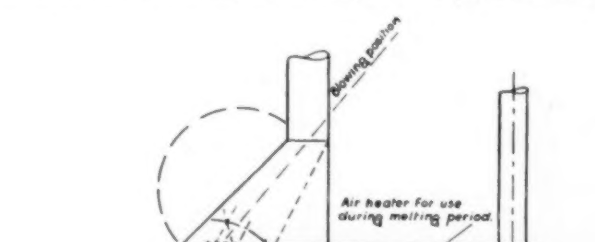


Fig. 3.—Arrangement of Stock Converter.

or without steel scrap, the pig-iron having a low sulphur and phosphorus content, because the process for foundry work is usually acid. Frequently the cupola and converter are so arranged that when the cupola is tapped the fluid metal runs direct into the converter.

The principle of the process of converting the molten metal into steel is the oxidation of the carbon, silicon, and manganese in the iron. This is done by blowing a stream of air either through or against the metal. When the air is passed through or against the metal, reactions take place, the oxygen of the air combines with silicon to form silica, with carbon to form carbonic oxide, with manganese to form oxide of manganese, and, if overblown, with iron to form oxide of iron. The success of this process depends upon the rapid production of heat by the combination of oxygen and the impure elements in the iron. During the first stage of the blow the silicon and the manganese are the first to combine with the oxygen, and the silica and oxide of manganese are present in the slag which is formed as a result of the oxidation. At this stage very little carbon is burnt out, but the temperature of the metal has increased considerably owing to the effect of the oxidation of the other elements. As the heat increases, the combustion of the silicon becomes more rapid, and the temperature of the metal is further increased. It is during this stage, known as the second stage, that the carbon is attacked, producing carbon monoxide, which is burned and converted into carbon dioxide at the top or nose of the converter. The escape of the carbon monoxide sets up a violent commotion in the converter, which causes the metal to boil. Gradually this ebullition of the metal subsides, as the carbon content is reduced, and the flame, which has been rising from the nose, dies down until there is not sufficient carbon monoxide being produced to support it. When the flame finally drops, decarburation is said to be complete. It is at this stage that ferro-silicon and ferro-manganese are introduced to recarburise the metal, the amounts added depending upon the qualities desired. The amount of phosphorus originally in the charge is not altered when an acid-lined converter is used, whilst with the basic converter the phosphorus is not removed until after the flame has dropped, during the "after blow." This latter process is not common with small converters.

There are several types of converters which operate on the same principle, but differ in design. In the Bessemer converter the air enters through bottom tuyères, while in a Tropenas converter the tuyères are at the side, and the air is blown on the surface of the metal. The object in each case is the same. With the Bessemer converter the air pressure varies from 20 lb. to 30 lb. per sq. in., according to the depth of the charge. There is a limit to the volume of air that can be admitted to the converter: when the volume is too great the chemical action is extremely violent, and cuts into the lining of the converter very rapidly. The pressure is, therefore, varied to suit the condition of the lining, the number of tuyères, and the head of metal in the charge. The operation frequently saturates the metal with oxygen, which is rarely completely removed by the deoxidising agents used. On the other hand, side-blown converters, like the Tropenas or Robert, do not need such high air pressure, 3 lb. per sq. in. being sufficient. More perfect combustion is associated with the side converters and this ensures a hotter metal, but involves a greater loss of metal through oxidation.

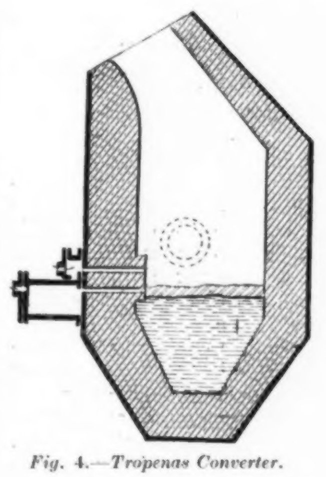


Fig. 4.—Tropenas Converter.

The Tropenas converter has two rows of tuyères close together, the top row being rectangular, and termed combustion tuyères, while the bottom row are circular, and termed reaction tuyères. The usual lining—acid—is silica or ganister. A sectional illustration of this type of converter is shown in Fig. 4.

In charging the Tropenas converter, it is first tilted to a convenient angle, and when the molten metal has been poured, it is brought back towards a vertical position until

the metal is level with the bottom row of tuyères, when the blast is turned on. The Tropenas converter process approximates very closely to the open-hearth process because oxidation is effected in both cases by a surface current of air, aided by ore additions in the latter process. The former, however, can be tilted so that the air pressure can be blown through the charge, or partly through the metal and partly over the surface. This gives a sufficient supply of free air to ensure combustion inside the converter.

The Stock oil-fired converter, illustrated in Fig. 4, is both a melting and a converting apparatus. Some points in favour of this type of converter are that practically no impurities are introduced into the metal from the fuel; the heat can be maintained indefinitely; the finished metal can be poured very hot; as a result it is suitable for the production of high-class thin and accurate work. Another important advantage is that the waste gases, during the time of melting, pass to a flue through an economiser, consisting of a series of pipes, through which passes the air required for the blow. The air is thus preheated to a temperature of about 400° C.

These converters are usually lined with silica bricks or special granular silicious refractory material, and therefore an iron low in phosphorus should be charged. The arrangement of the charge should be such that it protects the lining from the flame, and the scrap should be placed at the back, where it gets the full heat of the flame, as it melts at a higher temperature than the pig iron. Melting occupies about 1½ hours, with a blast pressure of about 12 oz. per sq. in. When the charge is melted, the blast and oil are turned off and the furnace turned into a vertical position for converting the metal. The blast for this purpose is increased in pressure to between 3 lb. and 4 lb. per sq. in. When the flame drops, an operation that occupies about 30 mins., the converter is tilted into its charging position, and the metal is recarburised by adding ferro-manganese or pig iron. After a ferro-silicon addition, the metal can be teemed into ladles.

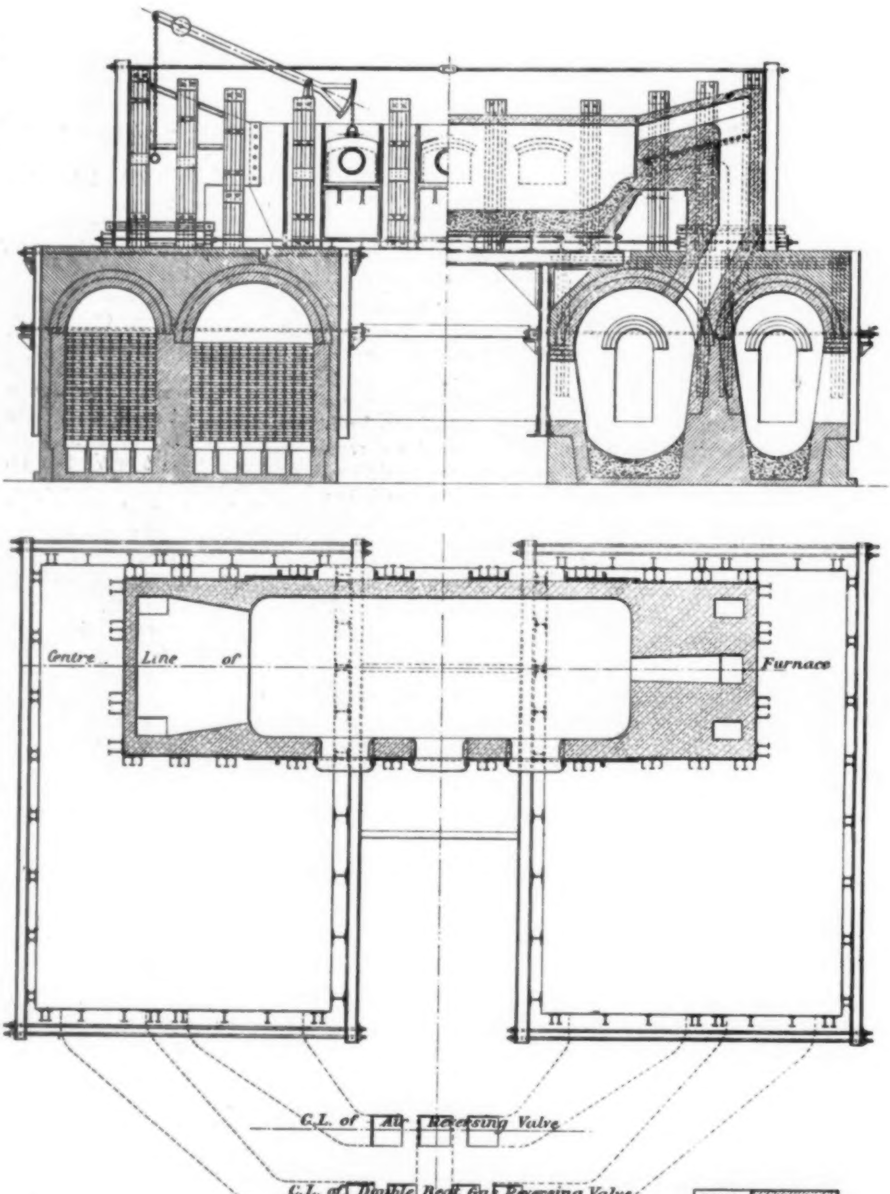


Fig. 5.—Modern Open-Hearth Furnace.

Open-Hearth Process.

The open-hearth process is that employed in foundries where very large castings are produced. The capacities of these furnaces range from 5 tons to 100 tons, but furnaces of the latter capacity are few, and a 50-ton furnace may be considered as being a large furnace. A special gas-producing plant is usually an integral part of the furnace as the oxidising flame is produced from a mixture of gas and air; but while this is the customary method, fuel oil, tar, coke-oven gas, and pulverised fuel are also used. Each method of firing has its adherents, but the determination of the fuel to be used depends to a great extent upon the geographical location of the furnace.

It has been described how the rapid oxidation of manganese, silicon, and carbon in a converter not only maintains the charge in a molten condition, but raises the temperature above the melting point of steel. It is by blowing air through the steel that this rapid oxidation is effected. Under ordinary conditions the maintenance of such a high temperature in the open-hearth furnace is not practicable. This difficulty is, however, overcome in the Siemens furnace by making use of the principle of regeneration. Thus, the waste heat of the furnace is used to heat the air and gas before they enter the furnace. In this way both the air and gas are raised to a high temperature, and this materially affects the intensity of the flame. The method employed in heating the gas and air, in the ordinary Siemens

(*Continued on page* 34.)

The Brackelsberg Process for Melting Steel.

Preheated air fed into the combustion chamber makes possible a temperature of about 1,800° C in this furnace with coal-dust as fuel.

THE melting process involved in the Brackelsberg furnace, which is fired with pulverised fuel, can justly be considered an important development, not only from a metallurgical point of view, but also in regard to melting technique. It was originally developed as an economical means of providing suitable metal for the production of grey and malleable-iron castings of high grade and uniform quality, and, as a result of a thorough official investigation carried out a little over a year ago, it was shown to have considerable advantages in comparison with most of the other cast-iron melting processes. The high temperature of the coal-dust flame, its uniform spread in the furnace space, its excellent heat transmission to the charge, the economical wear of the furnace lining, all represent notable features in the process. The short melting period permits a continuous operation during which the heat stored in the furnace lining is not lost.

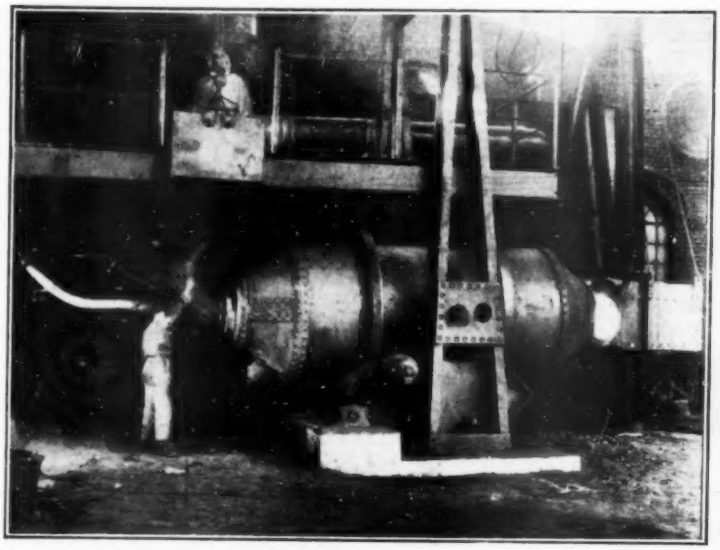


Fig. 1.—The Experimental Furnace.

In regard to quality of product, the official tests made, which have been supported by actual practice, indicated that the process eliminates, at lowest cost, the disadvantages which interfere with the assured production of material possessing uniform and high-grade qualities, when using a cupola or an air furnace, and makes it possible to utilise, in practical operation, the progress resulting from research, by avoiding the drawbacks recognised as detrimental to the production of high-quality castings.

Since these tests were carried out, considerable improvements have been made in the construction and working of these furnace plants, and with very favourable results on the whole melting process. The furnace temperature can now be increased to such an extent that steel can profitably be melted; this development is a result of preheating the air fed into the combustion chamber. Further, the furnace, which formerly could only be rotated around its longitudinal axis, can now, with the aid of toothed tilting segments, be tipped about its cross axis. Thus, the furnace, which consists of a cylindrical body with cone-shaped ends, is now capable of being rotated when in operation for melting, and can be tipped for tapping, charging, and relining, and the mechanism is so arranged that both rotating and tipping movements can be made simultaneously.

Experimental tests have been made on this equipment for melting steel, and a report* has been issued from the Kaiser Wilhelm Institute, Dusseldorf, by Dr. P. Bardenheuter. A furnace of 2 tons capacity, as shown in Fig. 1, was used. In order to raise the furnace heat quickly to a high temperature, it was found necessary to preheat the air, and for this purpose a simple recuperator was built. With the aid of hot exhaust gases, it was possible to preheat the air to about 300° C.

As a result of preheating the air in this way, temperatures up to 1,800° C. could be obtained without difficulty, and low-carbon steel scrap could be melted with reasonable quickness. No further obstacles interfered with the successful melting of steel in the furnace. The lining used was similar to that used in former investigations with grey and malleable cast iron, and consisted of a good quartzite refractory material with the necessary clay bond.

The charge for the first steel melted in this furnace consisted of 950 kilogs. of mild steel scrap and 50 kilogs. of hematite iron. The temperature of the preheated air was about 300° C., and the charge was fully melted in about 70 mins. after the lighting of the burner. After the temperature of the bath had been increased, additions of silicon and manganese were made as finishings to complete the melt, 0·30% of silicon and 0·5% of manganese being added. The furnace was tapped after a total melting time of 1 hr. 50 mins., when an optical measurement of the metal temperature registered 1,620° C. Small, thin-sectioned castings were made similar to those usually made in malleable cast iron. All the castings produced were quite sound, and some, in an unannealed condition, could be hammered out cold and bent to an angle of 180°, while others were hammered hot into blades about 0·5 mm. thick without the material showing signs of cracking at the edges. In view of the fact that melting took place at a rapid rate, in the first experimental melt, it was considered that the high proportion of pig iron in the charge, which forms a bath rapidly and quickens melting, could be eliminated. Another experimental melt was made for which the charge of 1,000 kilogs. consisted entirely of mild steel scrap. The time of melting and finishing corresponded with the former test, and the tapping temperature was 1,680° C. The casting properties and malleability of the steel were excellent. The results of these experimental melts clearly indicated that this process could be classified as a steel-melting process.

Further tests were made in order to define the proper melting procedure, having regard to the composition and quality of the metal. The fuel consumption, given in melts Nos. 1 and 2 of Table I., can be taken as reasonably accurate. A steel scrap was used for the tests, having a composition of approximately 0·21 C, 0·04 Si, 0·58 Mn,

* Published in "Stahl und Eisen," September 18, 1930.

0·041 P. and 0·05 S. The No. 3 melt consisted partly of metal from melt No. 2, as, after tapping about 300 to 350 kilogs. of the latter, about 40 kilogs. of grey Swedish pig iron was added to 500 kilogs. remaining in the bath. The Swedish pig iron contained 3·62% C and 2·24% Si. Later, further additions of 1 kilog. of ferro-manganese and 2 kilogs. of ferro-silicon were made. These additions added 0·30% C, 0·38% Si, and 0·16% Mn to the bath. The final

TABLE I.

RESULTS OF EXPERIMENTAL TESTS NOS. 1 AND 2.

—	Melt No. 1.		Melt No. 2.	
Charge :—				
Steel scrap........	772 kilogs.	815 kilogs.	806 kilogs	826 kilogs.
Spiegel	43 kilogs.		20 kilogs.	
FeMn additions ...	8·7 kilogs.		7 kilogs.	
FeSi ,,	8·0 ,,		10 ,,	
Melting down of charge	60 mins.		53 mins.	
Total operating time	120 ,,		108 ,,	
Temperature of air ..	240° C.		230° C.	
Temperature of furnace 15 mins. after melting down	1,630° C.		1,610° C.	
Temperature of furnace 30 mins. after melting down	1,690° C.		1,660° C.	
Temperature of iron when tapped	1,650° C.		1,660° C.	
Analysis.	Charge.	Final Sample.	Charge.	Final Sample.
	%	%	%	%
C	0·43	0·24	0·31	0·27
Si	0·04	0·28	0·04	0·14
Mn	1·00	0·50	0·77	0·20
S	0·047	0·059	0·049	0·055
P	0·039	0·062	0·040	0·057
Fuel consumption ...	153 kilogs. in 107 mins. = 86 kilogs./h.		154 kilogs. in 103 mins. = 90 kilogs./h.	
Up to melting down of charge (60 and 53 mins.)	86 kilogs.	= 10·4 %	79·5 kilogs.	= 9·5 %
Up to first test (98 and 87 mins.)	140 ,,	= 16·8	130·5 ,,	= 15·0
Total consumption (120 and 108 mins.)	172 ,,	= 20·7	162·0 ,,	= 19·2

sample of the metal in the melt gave a composition of: 0·47 C, 0·31 Si, 0·24 Mn, 0·054 P, and 0·053 S.

Similar raw materials were used in a further melt, No. 4, but without using pig iron. About 1,000 kilogs. was melted in 58 mins., and the operation completed in 1 hr. 50 mins. The temperature of the steel produced was 1,670° C. The final sample of the metal in this melt gave a composition of: 0·13 C, 0·27 Si, 0·11 Mn, 0·051 P, and 0·034 S. Round ingots of 50 kilogs. were cast from each of the four melts and rolled to 32 mm. square. Specimens were taken from each bar for tensile and Izod tests; two

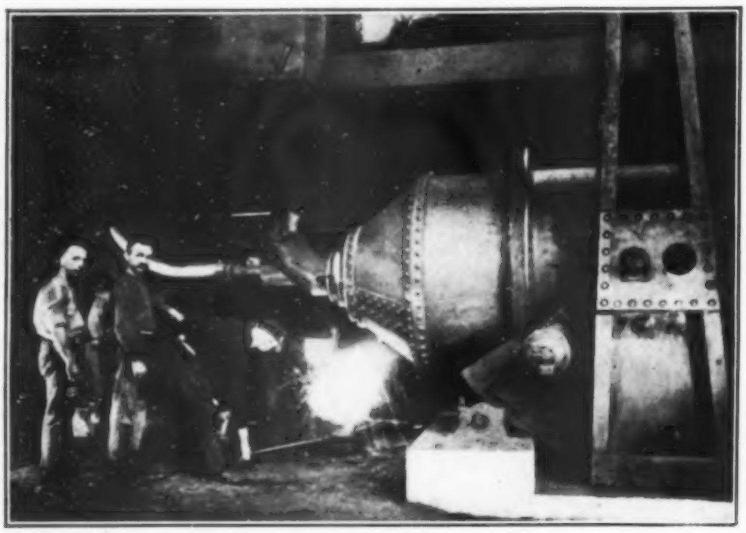


Fig. 2.—Tapping.

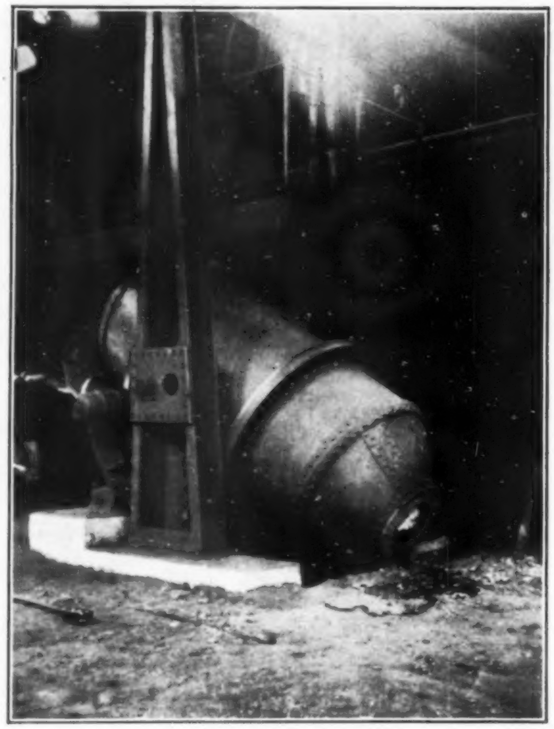


Fig 3.—Tilted for Charging or Relining.

bars each 20 mm. dia. and 200 mm. long, for testing tensile strength, and three bars, each 30 × 15 × 160 mm., with a 4 mm. notch, for Izod tests. These were annealed for 30 mins. above Ac_3 range, and the results from tests made on them are shown in Table II.

The fluidity of the metal was tested by casting a box of 100 sewing-machine feet from each melt in a dry sand mould. Although some parts of these castings did not exceed 1 mm. in thickness, in all cases they were well defined. Specimens from all melts were hammered out to blades 0·5 mm. thick, and into rectangular bars about 2 mm. wide and a metre in length. They showed no signs of brittleness, and the bars possessed sharp corners. The report emphasises the fact that even the steel from No. 4 melt, with only 0·13% C and 0·11% Mn, was free from brittleness, and the grain was very fine.

It is important to note that in the Brackelsberg process, with an acid-lined furnace, the melting down of the charge takes place quickly, as a result of combustion. There is no excess of air, and consequently the highest possible flame temperature is obtained. Further, the melting down is accelerated by rotating the furnace. Oxidation of iron and of its associated elements is low for a hearth furnace, but it is sufficient, except for a small amount of iron, to convert into slag a large part of the silicon and manganese present, as these elements reduce the ferrous oxide in the bath. The carbon assists in the reducing process, but not strong enough to boil the melt too much. As no ore or mill scale was used for refining in these experiments the carbon content of the bath was never less than 0·10%, even when the charge consisted entirely of

steel scrap. In common with acid-lined furnaces, there is a loss of manganese, as the manganese silicate in the slag is not appreciably reduced again by the carbon. In the same way, silicon losses cannot be avoided if the carbon content is low.

In comparing the analyses of the final sample taken with that of the charge, it will be found that for melts Nos. 1 to 3 there is an increase in phosphorus and sulphur. The phosphorus content is not increased during combustion (only alloys very low in phosphorus had been melted previously in the furnace), and it is thought that the differences in the phosphorus and also in the sulphur content are in the main due to the fact that the steel scrap used was not all of the same composition, so that it was impossible to ascertain the average analysis for the whole charge.

Whilst developing this furnace, remarkable progress was recently made by the inventor in cutting down the melting times as a result of modifications in the construction and working of the burner. The effect of these modifications is shown by the results of two further experimental melts.

In the first melt (No. 5) pure steel scrap was melted in the usual way; the final sample taken contained 0·14% C, 0·20% Si, and 0·16% Mn. The charge weighed 809 kilogs., melting down took 45 mins., and total operation time 73 mins.; the tapping temperature was 1,610° C. Tensile strength figures taken from bars rolled out of 50-kilog. ingots are given in Table II.

TABLE II.

TENSILE STRENGTH, ETC., OF IRON FROM EXPERIMENTAL MELTS.

Melt No.	Elastic Limit, Tons per Sq. In.	Tensile Strength, Tons per Sq. In.	Elongation, %.	Reduction of Area, %.
1	18·4	29·0	23·4	58·4
	18·4	28·9	23·0	56·7
2	17·3	29·0	23·6	58·2
	16·7	28·6	23·3	57·3
3	20·4	38·6	16·7	28·5
	20·9	38·6	15·7	32·8
4	16·6	25·8	27·7	69·4
	16·6	25·4	29·3	67·2
5	17·8	25·4	26·9	64·7
	16·8	25·4	26·7	64·6
6	—	53·5	10·0	19·8
		52·9	12·5	24·0

A second medium-carbon melt (No. 6), 0·78% C, 0·62% Si, and 0·48% Mn, of 780 kilogs. was made, the charge consisting of steel scrap and pig iron. Melting down took 45 mins., and total operating time was 67 mins. The casting temperature was 1,630° C., and the figures for tensile strength are also given in Table II. The life and malleability of these two melts were very satisfactory.

Compared to the melting times described above for the other four melts, this improvement in the burner means a reduction in melting times of about 40%.

A Summary of the Report.

The use of a simple recuperator to preheat the air fed into the combustion chamber to between 200° and 300° C., makes it possible to obtain temperatures up to about 1,800° C. in the Brackelsberg furnace, and ensures quick melting of steel. Up to the present the experiments made have been confined to the melting of steel in an acid-lined furnace. The metallurgical advantages of this process, which have already been referred to for producing grey and malleable cast iron, are of equal value when producing steel. Steel melted in this furnace is distinguished by its good mechanical properties, especial emphasis being laid on the remarkably good casting properties. The consumption of fuel when melting 1,000 kilogs. is proportionately no greater than in the largest Siemens-Martin furnace. On account of its low consumption of power, the Brackelsberg furnace is superior to any other furnace of the same melting capacity.

Bimetal—Its Function and Application

(*Continued from page* 19).

So far, only the thermal curvature of various metals due to temperature changes has been considered—that is to say, when heated indirectly or from an external source. Instruments of more recent design are often heated directly by the passage of an electric current. For such purposes as automatic safety devices, safety switches for motors, and such uses, it is desirable to use the same apparatus without alteration over the widest possible range of current intensity. In other words, an equal deflection and development of power is required over a very wide range of current intensity. This will necessitate the use of bimetals with widely differing specific resistances, but with very similar thermal characteristics. On every deflection curve in Fig. 6 the specific resistance in ohms. per metre per sq. mm. is indicated, and the values are also assembled in Table I. :—

TABLE I.

SPECIFIC RESISTANCE OF BIMETALS.

Bimetal.	Specific Resistance in Ohms/m/mm².
Invar — Cu	0·08
,, — Ni	0·177
,, — Fe	0·18
,, — Constantan	0·62
,, — 42% NiFe	0·73
,, — 27% NiFe + 5% Mo	0·82
42% NiFe — Ni	0·16
,, — Constantan	0·55
,, — 42% NiFe + 5% Mo	0·59
,, — 27% NiFe + 5% Mo	0·71

From this point of view the bimetal Invar-copper, with specific resistance of 0·08 ohms., would seem especially suitable, but it has already been pointed out that this suffers a mechanical defect, due to the comparatively low tensile properties of copper causing a consequent displacement of the zero point. This objection has recently been removed by the use of a Beryllium-copper alloy instead of copper. This alloy can be age hardened, and by suitable hardening and tempering, tensile properties comparable with those of Invar may be obtained. Moreover, the amount of Beryllium required to produce the desired improvement is so small as to have no appreciable effect on the conductivity of copper. This bimetal combination, therefore, leaves nothing to be desired. There are, however, several difficulties encountered in the manufacture of this bimetal. At the hot-rolling temperature the Beryllium alloy, just as in the case of copper, becomes much softer than Invar, and during the hot-rolling process is liable to spread out beyond the Invar. It is, therefore, very difficult to preserve exactly the proper relative thicknesses of the two sheets of such a bimetal. This combination should only be employed when everything else is impracticable. The bimetal Invar and pure nickel has quite a low specific resistance, namely, 0·17 ohms., and is therefore especially suitable in most cases where heavy currents have to be handled. Since pure nickel has a high temperature coefficient of specific resistance, this combination bends more and more as the current increases, and makes an excellent and accurate material for use with safety switches for motors. This combination has the further advantage of possessing remarkably good mechanical properties. In other combinations which are used, the specific resistances vary from 0·5 to 0·9 ohms./m/mm².

(*To be continued.*)

At a recent meeting of the Directors of the Electric Furnace Co., Ltd., it was resolved to pay the usual interim dividend of 3½% on the Preferred Ordinary Shares, on January 1st, 1931. The business now carried on by the Company has been established more than twenty years.

Reviews of Current Literature.

The Elements of Ferrous Metallurgy.

This is an elementary text-book on the science of ferrous metallurgy which embraces a very wide field in a remarkably efficient manner. It has for its object the exposition of the fundamental principles and methods involved in the manufacture and fabrication of iron and steel. The author emphasises the fact that this work is primarily intended as an introduction to the subject for students in technical schools and colleges. It aims to leave with the engineer a sound general knowledge of all important ferrous products without the encumbrance of a multitude of details which, the author asserts, are seldom retained and infrequently used, and also to give the student of metallurgy a foundation on which to build in the advanced course.

Opinions necessarily differ as to the best method of treating such a wide and involved subject. Authors have usually specialised in a particular branch or process, and they tend to emphasise and embrace details of their special section to the disadvantage of other sections of equal importance. In this work, however, with a few exceptions, the division and sub-division of the principles and methods involved have been considered with a good knowledge of the preliminary requirements of the student. Much valuable information has been omitted in order to conform to the object of the author ; the chapter on the blast-furnace, for instance, is confined to 33 pages, while the heat-treatment of carbon steels is condensed to 16 pages. It is rather surprising that the heat-treatment of alloy steels, with the exception of manganese steel, has been omitted entirely. In most cases, the author states, each particular alloy steel requires a special method of heat-treatment, and manufacturers make it their practice to send instructions which are often the result of extensive investigations. While this is true of special alloy steels, many are now in such common use that the usual form of heat-treatment employed for these steels could have been given with advantage. Heat-treatment has such an important influence on the structure and properties of steels that its value is increasing as knowledge of its function is developing.

The chapter on cast irons is somewhat brief even for a work of this kind, and that on malleable cast iron could have been extended somewhat with advantage. The reference to whiteheart malleable cast iron is not very clear. In this process the castings, after being annealed, have a white fracture, due to the fact that nearly all the graphitised carbon is removed, leaving carbon in the combined state.

Condensing such an involved subject to a work of 214 pages is an achievement on which the author is to be commended. In general, the main features are emphasised, and the work provides a useful source of information to the engineer. Its use will certainly save the student much valuable time, and enable him readily to obtain information of a fundamental character. The book is well printed, and contains 138 diagrams and illustrations and a useful index.

By Joseph L. Rosenholtz, Ph.D. Published by Messrs. Chapman and Hall, Ltd., 11, Henrietta Street, Covent Garden, London, W.C. 2. Price 15s. net.

Insurance Company's Technical Report.

There can be no doubt that careful investigation with a view to determining the causes of actual failure in materials under varying conditions of service is of considerable value. Such investigations give a clearer conception of the stresses to which parts are subjected under working conditions, and the results assist progress in the development of materials best suited to withstand the particular stresses to which they are subjected, and, in addition, facilitate the work of the designer. The question arises, in the very able Technical Report of the British Engine Boiler and Electrical Insurance Co., Ltd., whether future reports should be confined to special investigations into the cause of actual failures or into more general problems, rather than including a large number of accounts of failures from which the lessons to be learnt are obvious when the facts have been set out. Although design is now generally standardised, and faulty design is more frequently due to the demand for cheap production, investigations into the causes of actual failures are valuable in supplementing experimental research work. It is frequently difficult to devise conditions in a laboratory that conform to those operative in actual practice, and a report on the lines suggested would be of the utmost value to the engineering industry generally.

The character of this report was altered last year because it was considered that the use of welding was being allowed to develop in an uncontrolled and consequently dangerous manner, and that some registered authority ought to assume control. This suggestion has long been recognised, and, as our readers are aware, the Institution of Mechanical Engineers has now set up a committee to deal with the subject. The subject of fusion welding of pressure vessels has continued to receive the attention of the company, but in this report the matter on the subject is confined to their latest experiments on welding. They have found that as investigation proceeds the whole subject is full of riddles that have not yet been satisfactorily solved, and opinions frequently expressed have been found to require verification. Though much research has been carried out by various people, there are various points requiring elucidation not yet settled, and there is scope for much further research work, preferably of a disinterested character.

Among the investigations referred to in this report is one on the "Weldability of High-tonnage Plates," in which tests were made in welding plates of various carbon contents with the same electrode, with a view to determining the change in strength and ductility. It was found that there was nothing to choose between the quality of fusion obtainable with any of the plates. With some exceptions the parent metal showed an overheated structure near the junction. The observations showed no intrinsic objection to the plates used being welded, provided that the welded plate is normalised and a good-quality welding rod with the requisite strength used. Apart from these provisions, the main criterion is the obtaining of weld metal with high ductility and toughness.

Another experiment referred to the "Welding of 3% Nickel Steel." Tests were made on welds made under various conditions by different makers. In general, the tests on a metallic arc weld showed that the ductility and toughness are improved by heat-treatment above the critical range, without loss in tensile strength or hardness. The weld-metal showed an exceedingly good shock-resisting capacity, and stood up well to hot work, but the plate was hardened by water-quenching treatments, after which it could not be deformed without breaking. Although nickel has in the past been considered detrimental to welding, the weld gave no indication to this effect.

In addition to many other experiments on fusion welding, tests are given on welded cast iron, the results of which compare with those from tests given in the last report. Further tests have also been made in welding copper plates. In these tests the microstructure showed good fusion, but disclosed that the grains of the parent metal near the junction had been enlarged.

The report deals with the investigations carried out on a wide range of actual failures, and, in addition, it contains articles on "Variable Speed Polyphase A.C. Commutator Motors," by D. C. Bacon, M.C., A.M.I.E.E. ; and the "Protection of Low-pressure Steam Vessels when Supplied Through a Reducing Valve," by L. W. Schuster, M.A. This report is full of interest, and is well produced. The illustrations and diagrams referred to in the text are reproduced on special art paper to preserve as true a reproduction as possible so that the illustrations, particularly the photomicrographs, can be really valuable. It contains 209 pages of text matter and tables, and, in addition, 154 illustrations.

British Engine Boiler and Electrical Insurance Co., Ltd. Price 7s. 6d.

The Modern Blast Furnace and its Operation

By R. A. Hacking, M.Sc.

Part VI. Chemical Principles.

Introductory—The Reduction of Iron Ores—Reactions between Iron Oxides and Carbon Monoxide—Dissociation of Carbon Monoxide—Application of these Equilibria to Blast-furnace conditions—Discrepancy between Counter-current and Equilibrium conditions—Rate of Change of Composition under Counter-current conditions.

THE reduction of oxides to the metallic state may be effected in a variety of ways, among which may be enumerated :—

(1) Direct dissociation to the constituent elements, metal and oxygen, by heating to a temperature at which the " dissociation pressure " of the oxide is greater than the oxygen pressure of the surrounding atmosphere. For example, mercuric oxide dissociates to mercury and oxygen at a temperature below a visible red heat. Obviously, the process is expedited by a reduction in pressure.

Only those oxides whose dissociation pressures are relatively high can be reduced by this means—viz., the oxides of the " noble " metals—gold, silver, platinum, mercury, etc. The dissociation pressures of the oxides of iron are so low as to place this method of reduction beyond the bounds of possibility in the case of that element.

(2) Reduction of oxides by metals whose oxides have lower dissociation pressures than the one to be reduced. The metals which find application in this respect are those whose oxides have extremely low dissociation pressures—viz., the " base " metals—sodium, potassium, calcium, silicon, aluminium, manganese, etc.

Practical examples of this method of reduction are the Goldschmidt process for the production of chromium and manganese from their oxides by means of aluminium, and the use of manganese, silicon, aluminium, titanium, calcium, magnesium, etc., as " killing " agents or de-oxidants in steel manufacture.

(3) Reduction by certain non-metallic elements which have a great affinity for oxygen. For example, hydrogen has a powerful reducing action on some metallic oxides, thus :—

$$M_xO + H_2 \rightarrow {}_xM + H_2O$$

Other metallic elements are readily oxidised by water vapour, thus :—

$${}_xM + H_2O \rightarrow M_xO + H_2$$

Other elements show both reaction directions, dependent upon the temperature and the ratio of hydrogen to water vapour in the gas phase.

(4) Reduction by means of carbon monoxide, thus :—

$$M_xO + CO \rightarrow {}_xM + CO_2$$

In the case of the oxides of iron, both reaction directions are shown, depending upon the temperature and the ratio of carbon monoxide to carbon dioxide in the gas phase. Thus :—

$$FeO + CO \rightleftarrows Fe + CO_2$$

The Reduction of Iron Ores.

The reduction of iron ores in the open forges of the ancients was effected primarily by means of solid carbon in the form of charcoal. The development of the counter-current principle from thermal considerations was equally applicable to the chemical phenomena of the process. With the progressive lengthening of the shaft of the iron-reduction furnace, and other corresponding thermal developments, the reactions between iron oxides and carbon monoxide became of paramount importance. This fact was soon recognised, and in 1862 Grüner propounded his famous theorem, which held undisputed sway for many years amongst blast-furnace operators. Further developments along the lines outlined in previous articles of this series led to operating results which obviously challenged the complete accuracy of Grüner's theorem. During recent years, further light has been thrown on the complex reactions of the process by American, Continental, and British research workers.

It appears advisable at this juncture briefly to survey the chemical principles of the blast-furnace process in the light of these results.

Reactions Between Iron Oxides and Carbon Monoxide.

The three oxides of iron react with carbon monoxide according to the following equations :—

$$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2 \quad \ldots.(1)$$

$$Fe_3O_4 + CO \rightleftarrows 3FeO + CO_2 \quad \ldots.(2)$$

$$FeO + CO \rightleftarrows Fe + CO_2 \quad \ldots.(3)$$

Reaction (1) is irreversible, but reactions (2) and (3) are reversible, and may proceed in either direction, dependent upon the conditions. The composition of the gas phase—that is, the CO/CO_2 ratio—at the equilibrium point where such a reaction comes to rest, is dependent on the temperature, but not upon the pressure, since neither reaction involves a change in the gas volume. The equilibrium values of both reversibles are shown by the curves (2) and (3) in Fig. 6.

In addition, ferrous oxide and metallic iron react with carbon monoxide to form iron carbide and carbon dioxide, according to the following equations :—

$$3FeO + 5CO \rightleftarrows Fe_3C + 4CO_2 \ldots\ldots\ldots(4)$$

$$3Fe + 2CO \rightleftarrows Fe_3C + CO_2 \ldots\ldots\ldots(5)$$

Both reactions are reversible, the CO/CO_2 ratio of the gas phase at equilibrium in both cases depending on the temperature and the partial pressure of the two gases. These equilibrium values are depicted by curves (4) and (5) in Fig. 6. They are corrected for the partial pressures of $CO + CO_2$ given by Schlesinger and Metz (Stahl und Eisen, 1911) for various temperature levels in a working blast furnace.

Dissociation of Carbon Monoxide.

Under certain conditions, carbon monoxide dissociates to carbon and carbon dioxide. The reaction requires for its initiation the presence of a suitable catalysing surface, such

as metallic iron or nickel, FeO, Fe_3O_4, etc. The reaction—

$$2CO \rightleftharpoons C + CO_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

is reversible, and the ratio of CO to CO_2 at equilibrium is dependent upon the temperature and the partial pressure of those gases. The equilibrium values of this system at various temperatures, and a pressure of one atmosphere, have been determined by Boudouard and by Rhead and Wheeler. They are shown, corrected for pressure as before, in curve (6) in Fig. 6.

Application of these Equilibria to Blast-furnace Conditions.

Having very briefly surveyed the building-up of the temperature-gas composition diagram incorporating the equilibrium curves of the reactions involved in the reduction of iron oxides by carbon monoxide, it is interesting to compare it with the gas composition curve of a working blast furnace. The information regarding the gas composition at various levels inside the shaft is at present rather scanty. The figures given by Schlesinger and Metz are incorporated in the curve G, shown in Fig. 6.

It will be seen that the gas-composition curve lies wholly in the phase fields, where metallic iron (or its carbide) is stable—that is, the gases are strongly reducing in regard to the oxides of iron all the way from the stock line until the combustion zone is reached.

It will be observed, in relation to the $C/CO/CO_2$ system, that at temperatures below about 1,300° F. the curve G lies in a phase field in which carbon monoxide is unstable, and the reaction tends to proceed from left to right ("carbon deposition"). The curve G, however, crosses the equilibrium curve at about 1,300° F., and above this temperature the opposite tendency prevails—that is, the reaction proceeds from right to left ("carbon solution").

Discrepancy Between Counter-Current and Equilibrium Conditions.

The curves (2) to (6) in Fig. 6 refer to equilibrium conditions in the respective systems. The attainment of equilibrium is dependent upon the time factor—that is, the period of contact of the phases or materials concerned. In any process based upon counter-current principles, this time factor is limited. Thus, whilst the descending solids may take anything from 8 to 16 hours to descend from stock line to tuyères in the modern blast furnace, the ascending gases traverse the distance in approximately 1 to 4 secs. It is evident from the curve G in Fig. 6 that the gas phase does not attain equilibrium, especially at low temperatures, when the curve G is above *all* the equilibrium curves.

The very great difference in the speeds of the two counter-currents—descending solids and ascending gases—largely accounts for the fact that whereas all reduction of iron oxides is complete in the best practice before three-quarters of the distance has been traversed, oxidation of the gases—*i.e.*, to the equilibrium point—is very far from complete at the time they leave the counter-current. Other factors, however, are to be considered.

Rate of Change of Composition under Counter-Current Conditions.

In this regard, Korevaar ("Combustion in the Gas Producer and the Blast Furnace") has evolved the following expression :—

$$\frac{dx}{ds} = K \frac{\text{Reaction velocity}}{\text{Velocity of reactant}}$$

where—

$\frac{dx}{ds} =$ rate of change of composition of reactant with distance.

$K =$ a factor indicating the properties of the surface of the solid reactant.

The reaction velocity is dependent upon :—

(*a*) The temperature, to which condition may be allied the rate of supply of thermal units.

(*b*) The distance from the equilibrium point of the system or systems concerned. Bone and his collaborators (J.I.S.I., 1927, I., and 1930, I.) have termed this the "Distance Potential." They have demonstrated effectively that the speed of reaction slows down progressively as equilibrium is approached.

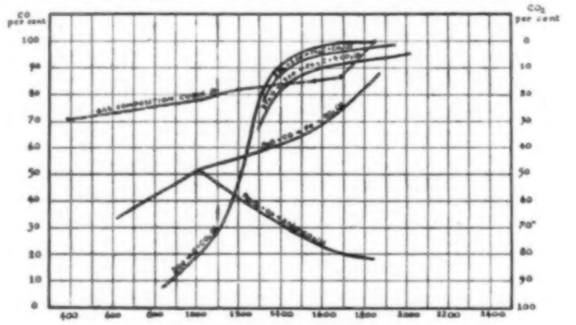
The above expression may now be applied in considering the progressive changes in composition of the two counter-currents of the blast-furnace process.

(*a*) *The Ascending Gases.*—In order to simplify matters, the $CO + CO_2$ of the gases is considered as 100% throughout this section.

The gases leaving the combustion zone are composed of 100% CO. At the high temperatures obtaining in the bosh, reaction occurs with some of the oxides of the metals and metalloids present, with the production of metal or metalloid plus CO_2. In addition, the "carbide" reactions are also tending to produce CO_2. The velocity of the reaction—

$$C + CO_2 \longrightarrow 2CO$$

—is very high at these elevated temperatures, and the equilibrium value of this system is at 100% CO. Thus, in spite of the high gas velocity, any CO_2 produced by reduction of oxide to metal, or by the carbide reactions,



TEMPERATURE—DEGREES F.

Fig. 6.—Temperature/Gas Composition Diagram for Blast-furnace Conditions. ($CO + CO_2$ considered as 100%.)

immediately disappears through reaction with the coke or with carbon deposited at lower temperatures higher up the shaft. The higher the temperature, the more likely is the coke to be the source of carbon involved.

As the gases ascend the shaft, the tendency to the production of CO_2 becomes greater, since the gases are now encountering more and more unreduced oxide of iron, whilst the velocity of the $C + CO_2 \longrightarrow 2CO$ reaction is decreasing. About 1,800° F. the zone of limestone dissociation is reached, and this, in conjunction with the presence of more unreduced FeO, causes the formation of a considerable amount of CO_2. The velocity of the $C + CO_2 \longrightarrow 2CO$ reaction is now so reduced as to be unable to dispose of this CO_2. Below 1,800° F. the equilibrium curve of the $C/CO/CO_2$ system leaves 100% CO, and swings away rapidly. It intersects the gas composition curve G at about 1,300° F. Thereafter, all the reactions involved are tending to produce CO_2, as a stable product. Thus, after the first appearance and rapid rise in the CO_2 content, there is a gradual increase which is continued more or less all the way to the stock line.

As the gases ascend and the temperature falls progressively below 1,300° F., the velocities of the reactions (2) and (3) decrease owing to the lower temperature. Therefore, the rate of CO_2 production from these sources falls off. The curve G is now in the field of "CO instability" in regard to reaction (6), and "carbon deposition" occurs to an increasing extent as the distance from equilibrium increases—see curve (6)—until at 850° F. it attains a maximum. At this point this reaction is probably the chief source of CO_2 production. Below this "optimum" temperature, the rate of production of CO_2 from this reaction decreases progressively until the stock line is reached.

(To be continued.)

Recent Developments in Tools and Equipment

Improved Hump Method of Heat-Treatment.

A RECENT development has been incorporated in the Hump method for the heat-treatment of steel. This method depends upon the thermal change-point of steel. The Hump equipment consists primarily of a vertical furnace wound with resistance wire, and a very sensitive thermocouple, which is inserted through the bottom of the furnace, so that the hot junction of the couple is near to the centre of the work. In addition, the equipment is provided with an automatic temperature recorder which draws a temperaturate curve on a chart. The curve drawn by this recording instrument shows the temperature and time at which the charge reaches its critical change-point and produces an indication in the form of a hump in the curve. Quenching is done at a predetermined interval after the hump appears, so that it and all subsequent operations depend upon accurate knowledge regarding the proper interval between the critical point and the quench. This brings the control of the quenching point definitely in the hands of the operator.

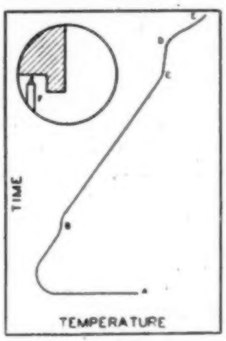


Fig. 1.

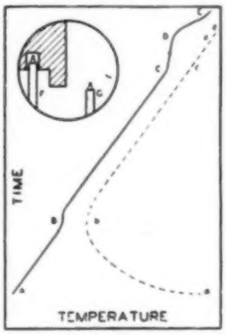


Fig. 3.

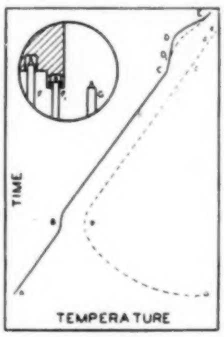


Fig. 3.

The latest improvement now embodied in this heat-treatment equipment is a means for accurately controlling the rate of heating in addition to control of quenching or soaking point. This improved Hump method comprises the usual Hump furnace, the control panel fitted with relays, contactors, switches, and fuses, and a special 2-point potentiometer, which is called a combination recorder and recording controller.

To control the rate of heating in and above the critical as precisely as below it, the simple, manual setting for constant heat input can be elaborated. Where the nature of the work requires, input can be reduced as the hump begins, and resumed as it ends, so that the temperature difference between work and furnace is not increased during the critical. This can be done manually with the regular hump equipment, but the human element may be eliminated, if desired, by controlling the rate of heating automatically.

It is for this purpose that a combination recorder and recording controller is being installed in place of a simple single-point temperature recorder. This instrument draws two dotted lines on the chart. One dotted line shows the temperature of the work, and another dotted line shows the difference between the temperature of the work and that of the furnace. This difference in temperature is controlled automatically to prevent the building up of an excess temperature difference between work and furnace at any point in the heating cycle.

The value of this improvement is more clearly indicated by reference to the heating curves produced on the charts; Fig. 1, for instance, shows the standard Hump curve drawn by the single-point recorder used in the simple Hump method, with uniform heating of the furnace. A B represents the drop in temperature when the cold work is placed in the furnace. Work and furnace equalise at B, at which point the power is turned on. B C shows the rate of heating below the critical, C D the critical, and D E the rapid rate and short time above the critical to the point at which quenching takes place. The thermocouple at F, it will be noted, is close to the work. The experimental chart in Fig. 2 carries the idea further. It shows as a solid line record A B C D E, the record that would be drawn if, instead of the standard thermocouple placed close to the work, as in Fig. 1, this thermocouple were buried in the work at F. Another "couple" located at G, in the furnace away from the work, would show the furnace temperature as the dotted line *a b d c e*. The dotted curve, representing the furnace temperature, would be a smooth curve falling from *a* to *b*, as the work chilled the furnace, then rising at a constant rate through *c d e* after the power is applied at *b*.

The chart, Fig. 3, shows that not only will this constant heat input bring about a rapid rate of heating from D to E, but that light sections or corners (affecting thermocouple buried at F_1) may be forced through the critical at D_1, ahead of heavy sections at D (affecting thermocouple buried at F), and various sections may, therefore, be coming out of the critical at different times, as shown by the varying length of the lines C D_1 and C D. Fig. 4 shows the ideal Hump curve (thermocouple at F) to correct these difficulties, and which can be secured through intelligent hand control of the standard Hump equipment, but which is facilitated and the human element removed by automatic control.

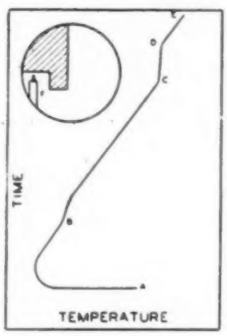


Fig. 4.

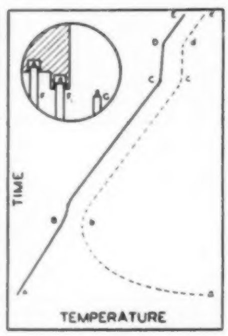


Fig. 5.

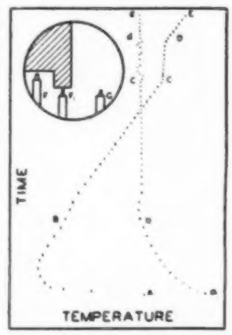


Fig. 6.

The chart, Fig. 5, shows how a buried thermocouple that would draw a solid, work-temperature line A B C D E (from a thermocouple buried at either F or F_1) compares with the dotted furnace temperature line *a b c d e* drawn by a thermocouple located in the furnace (at G) away from the work. The temperature difference is constant all the way from B to E, and this can be secured by hand control with reduced heat input during the critical, or the control can be automatic.

In Fig. 6 the Hump temperature-difference controller, which provides automatic heat control, assures the ideal curve as in Fig. 4, and draws this curve as a dotted line A B C D E from a thermocouple located close to the work,

whether at F or F_1. The instrument is a combination 2-point recorder and recording controller, however, operated from two thermocouples at F or F_1 and at G, which thermocouples are opposed. The dots forming the work-temperature curve from the "couple" at F or F_1 are drawn by the same pen as the dots forming the temperature-difference or

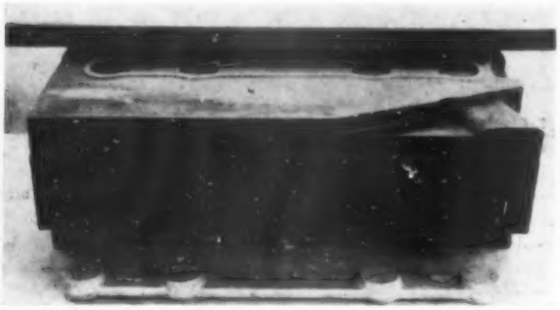


Fig. 7.—Die-block Treated in the Improved Hump Furnace.

control curve *a b c d e* from "couple" at G. The pen alternates between one curve and the other. When drawing the work-temperature curve, only that thermocouple is effective which is next to the work at F or F_1; but when the controller-curve dots are being drawn from "couple" at G, the impulse received by the instrument comes both from the thermocouple at F or F_1 and that at G, but so connected as to oppose each other, and the quantity recorded is, therefore, the difference in temperature between the work thermocouple F or F_1, and the furnace thermocouple at G, or between the work and the furnace.

The controller can be so set that this difference shall be the number of degrees required to give the desired rate of heating of the work. If it becomes greater, the heat input is reduced automatically. If it becomes less, the heat input is increased automatically. Thus, the difference controller holds the temperature difference constant, prevents light and heavy sections of the work passing through the critical in different lengths of time, prevents a

Fig. 8.—New Equipment Recently Installed.

more rapid rise in temperature above the critical than below it, and performs these important functions automatically, eliminating the human element.

This improved Hump furnace of the Leeds and Northrup Co., of which the sole British agents are the Integra Co., Ltd., has met with considerable success for accurate hardening drop-forge dies and rolls for rolling mills. One firm, although only starting this equipment at the beginning of this year, has treated 175 large die-blocks, one of which is shown in Fig. 7, and there have been no losses either through cracking or warpage. It has not been possible to determine the increase in die life, as the dies are still in use, but additional equipment now being installed, of a similar type, and shown in Fig. 8, is a reasonable indication that the results are satisfactory.

Blowpipe for Heating Surfaces.

A NEW heating blowpipe of great capacity has recently been made which has successfully passed many severe tests. This blowpipe, which is shown in the accompanying illustration, has been designed especially for use with oxygen and dissolved acetylene on the "non-injector" principle, and embodies a simple device by which the danger of back-fire is practically eliminated. It is capable of passing quantities of gas from 300 to 150 cub. ft. per hour of each, and provide a flame similar in shape to the ordinary welding flame, but of greater bulk.

The average engineer is so accustomed to regard the oxy-acetylene process as a means of welding or metal cutting that he is apt to forget its value for heating purposes. Much useful work in this way can be done with an ordinary welding blowpipe, but for heavy sections of metal,

A.-L. "Magnum" Blowpipe for use with Oxy-Acetylene.

from 300 to 450 cub. ft. of each gas per hour, and, as shown, it is provided with tips and heads to suit a variety of requirements. The head shown in position on the blowpipe provides a deep brush-like flame in the form of a rectangle at right angles to the blowpipe, while the head immediately to the right of it provides a still deeper flame, wedge-shaped, as there are two lines of gas orifices splayed out at an angle of about 25°. This is a most useful head for heating up large surface areas. The tips on the right pass varying which must be straightened or set, considerable heat must be spread over a wide area, for which purpose the ordinary blowpipe is insufficient, even with the largest head available. This new blowpipe has been definitely designed for this purpose, and in many tests that have been made it has successfully demonstrated its value for straightening and removing twist from plates by the application of heat, for which purpose it has been instrumental in saving much valuable time.

Tube Materials for High-pressure Water-Tube Boilers

By S. F. Dorey, M.Sc., Wh.Ex., M.I.Mar.E.

The success of the high-pressure water-tube boiler is dependent on the quality of material used for the tubes, for which alloy steels are considered to be more suitable than mild steel.

THE necessity for increased economy in shipping was never of more vital importance than at the present time. In order to achieve the best results, those engineers who are more especially concerned with the steam engine are now devoting very considerable attention to the possibilities of improving the efficiency of the prime mover. To do this it is essential to increase the steam pressure and the steam temperature, and from practical considerations, this is only possible by the adoption of the water-tube boiler. The satisfactory experience gained in the operation of high-pressure land boilers and the improved efficiency obtained therefrom in comparison with boilers of moderate pressure should give confidence to the expectation that similar results will hold for marine work.

A vital feature of water-tube boilers is, of course, the tubes, and a paper dealing with the design, working conditions, factors of safety, and materials for tubes of marine water-tube boilers was presented before the members of the Institute of Marine Engineers on November 11, by Mr. S. F. Dorey. For convenience, he divided the subject into six sections. The first dealt with the stresses in boiler tubes, due to internal pressure and temperature, the second was devoted to tube temperatures, while in the third section the materials for tubes were discussed. The fourth section contained suggested formulæ for calculating the thicknesses of tubes for high-pressure marine water-tube boilers, and the factors of safety associated with the suggested thicknesses were dealt with in the following section. Finally, some particulars were given in regard to the behaviour in service of high-pressure boiler tubes. The attention given to materials for tubes was very considerable, from which the following has been extracted :—

Materials for Tubes.

The ultimate success of the high-pressure water-tube boiler depends largely upon the quality of the material used for the tubes, and an assurance of homogeneous material is particularly desirable. Soft mild-steel tubes have been used largely on account of their relative cheapness and ease of manufacture, but with the high pressures and high temperatures now being adopted, the author gave special attention to alloy steels, which are more suitable.

So far, for water-tube boilers, there appears to be no necessity for departing from the use of low-carbon steels, but undoubtedly there is a call for the soundness of steel used in the manufacture of tubes, and reliability against segregation and the troubles that arise from it, most prominent amongst which is corrosion.

Tubes for water-tube boilers are usually specified to be cold drawn and weldless, and manufactured from steel made by the Siemens-Martin open-hearth process, the percentage of sulphur and phosphorus being stipulated not to exceed, say, 0·035 and 0·03 respectively. The tests specified by most authorities consist of tensile, flattening, crushing, and bulging or expanding tests, together with hydraulic pressure tests. In regard to the tensile tests, some authorities quote a maximum strength without a minimum, others a minimum strength or a range of strength, the limits being for ambient temperatures. The tubes are also required to be free from surface defects, which incidentally may be inherent in the material or caused in the process of manufacture. Frequently the material is required to comply with a chemical specification, but this may be no guarantee that certain of the constituents are evenly distributed throughout the material, and it is this lack of homogeneity which causes corrosion. The most easily detected segregates are those due to the presence of sulphur in steel, which occurs as sulphide of manganese or the double sulphide of manganese and iron, and these sulphides show up best by sulphur printing.

To ensure satisfactory material it is essential that, as any segregation present in the tubes must necessarily have been present in the original ingot, an examination by sulphur printing should be made at the earliest stages of manufacture, either in the original ingot or in the billets made from it. The association of corrosion and pitting in tubes with the presence of segregates has been convincingly dealt with by Messrs. G. R. Woodvine and A. L. Roberts.[1] These authors made sulphur prints from a number of new tubes taken at random from various consignments, and found them badly segregated on the inner surface, the sulphur content at the inner surface being $2\frac{1}{2}$ to 3 times that at the outer zone. Tests carried out on two samples of superheater tubes for a period of one year, one segregated on the inside and the other free from segregates resulted in the segregated tube perforating, whereas the unsegregated tube was little the worse for wear. While the activity of the corrosion may not have been entirely due to the segregated matter, it does, however, emphasise the necessity of obtaining steel as free as possible from sulphide inclusions. Ultimately these authors were able to purchase ingots made with all the care devoted to the making of high-grade alloy steel ingots, and all tubes made therefrom were found free from segregates. It would, therefore, appear desirable that all water tubes of mild steel should be made of homogeneous material, having a low sulphur content equally distributed throughout the material, and to ensure that this is the case, sulphur prints should be taken from the original ingots or the tube billets. Further, to ensure absence of hair lines on the outer surfaces of tubes, the tube billets should be machined to remove any mill scale. Similar remarks will apply to superheater tubes where mild steel is used, but as the working temperature is increased it becomes necessary to study the behaviour of the material at elevated temperatures.

For tube material it is essential that the steel or alloy should be capable of resisting oxidation at the service temperature, and be able to resist satisfactorily for a prolonged period the stresses to which it is subjected. The high temperature steam in contact with the inner surfaces of the tube is more likely to cause oxidation than hot gases in contact with the outer surfaces. In some cases in order to protect the external surfaces of tubes from oxidation the material has been coated with an alloy metal by means of a "calorising" or "aluminising" process. Experiments have shown, however, that with furnace gases having a

1 "The Influence of Segregation in the Corrosion of Boiler Tubes and Superheaters." (Iron and Steel Inst., vol. cxiii.)

CO_2 content above 12–14%, the temperature at which oxidation commences is considerably higher than the metal temperatures likely in present practice.

Experiments carried out at the Royal Technical College, Glasgow, have shown that there is a slight dissociation of the steam with probable oxidation of the metal which may have some effect about 900° F., but the pressure adopted in these experiments was comparatively low, and it is known that dissociation is checked by an increase in pressure. Mr. R. H. Collingham[2] has stated that the British Thomson-Houston Co. had considered the problem, and did not expect dissociation to be sufficient to cause any trouble in boilers at pressures and temperatures considered suitable in the light of present knowledge. American investigations have also proved that for mild steel dissociation occurs at temperatures above 500° C. It will, however, be shown later that considerations of strength limit the use of mild steel to temperatures not greater than 900° F., so that with proper design and care to prevent excessive temperatures serious trouble due to oxidation should not be experienced. For land work the latest developments include a superheated steam temperature of 1,000° F., which necessitates the employment of some alloying element such as nickel and chromium, which will make the material more resistant to oxidation.

Some interesting particulars of experiments carried out to determine the resistance to oxidisation of heat-resisting steels are given by Messrs. Robert Waddell and Laurence Johnson.[3] According to these authors, high chromium irons and nickel chromium austenitic steels were unattacked by steam at 550° C. and by furnace gases at 850° C.

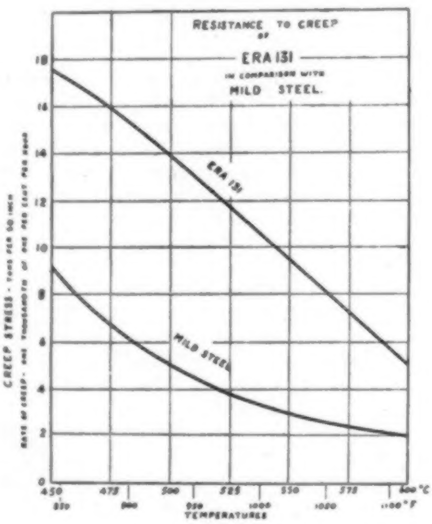


Fig. 16A.

The approximate temperatures at which oxidation may start having been determined for any particular steels, it becomes necessary to consider the strength of the materials at these high temperatures. As the temperature of a metal is increased it is found that there is a limit at which the physical properties of the material change, and in recent years much attention has been given to ascertaining a suitable criterion of strength at elevated temperature. It has been found that at a certain temperature materials behave in a manner resembling a viscous fluid, and under stress deformation continues for various periods, depending on the intensity of stress. As a result, much research work has been and still is being carried out to ascertain whether there is a definite stress for each material and temperature at which deformation or creep ceases. The methods adopted in determining the rate of creep, and some particulars of the results for certain materials, have recently been given by Mr. S. L. Archbutt,[4] and it is not proposed to go into any further details here. Attention has more recently been given to the determination of the stress at which the rate of creep will not exceed a permissible amount, thus allowing for a known extension to take place for a given life, and the strength of the material is thus expressed in terms of temperature and time. In this manner it is found possible to use ordinary carbon steel at higher temperatures than has previously been thought desirable. The working stresses are, however, based on considerations of plastic distortion, as any attempt to consider the applicability of the elastic theory for temperatures above, say, 750° F., must be questioned, as will be apparent from Fig. 2, which shows the variations of the so-called constants E, a, σ, K, and the products Ea and $\frac{Ea}{K} \times 10^4$, with temperature for ordinary mild steel used in the manufacture of boiler tubes. The values of E lb. per sq. in. are the mean of those given for 0·17 C and 0·24 C steel in E.R.S.R. No. 1, those for a being the mean for 0·09 C and 0·22 C steel (see Driessen's results for 0·09 and 0·22 carbon steels, "International Critical Tables," Vol. 2, p. 470).

The values of K are taken from the experimental results of K. Honda and T. Simidu. (Science Reports, Tôhoku University, Sendai.)

The approximate values of σ calculated by means of equation—

$$\sigma = \frac{E}{2N} - 1$$

—are also shown in Fig. 2.

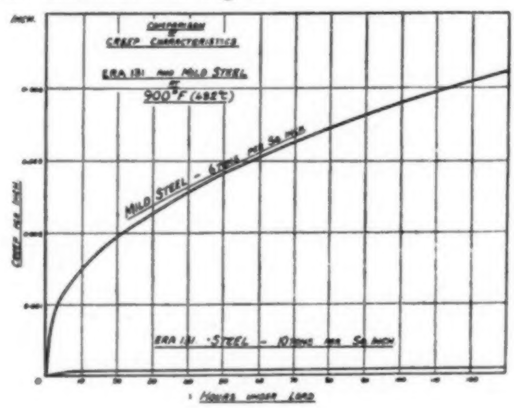


Fig. 16B.

It will be observed that at temperatures above 450° C., the value of E falls off rapidly, and also that Ea is practically constant up to 400° C. (752° F.). For the purpose of stress calculations above 750° F. it would therefore appear that no reliability could be placed on the values of E for ordinary mild steel, and consequently on the values of the stresses deduced by the theory of elasticity. For higher temperatures that might possibly arise in superheater tubes, it is safer to assume that after a period of time plastic conditions ensue, and the stress becomes uniform across the tube wall.

Mr. H. L. Guy[5] has shown how ordinary carbon steels may be used at temperature of 900° F. with the same factor of safety—that is, with the same creep rate—as at 700° F., provided the working stress is reduced by 60%.

In order to ensure greater safety at high temperatures, steel manufacturers have investigated the alloying of certain elements, such as chromium, nickel, molybdenum, tungsten, vanadium, manganese, and silicon, with ordinary carbon steels, so that increased strength will be attained. For boiler tubes it is essential that the addition of any of these elements should not interfere with the mechanical properties of the material at ambient temperatures—that is, the material must be capable of being bent and expanded cold,—and for certain types of superheater tubes it must be possible to weld the material. So far there is little available information of the behaviour of alloy steel tubes under service conditions, though there is a fair amount of information regarding their properties. The chief reason that

2 Discussion on "High-pressure Steam," I. Mech. Eng., 1927, p. 180.
3 "Tubes in Steam Engineering." (Liverpool Eng. Soc., vol. li.)
4 "Recent Metallurgical Research in Relation to Marine Engineering." (Inst. of Marine Eng., April 8, 1930.)

5 "Tendencies in Steam Turbine Development," Inst. of Mech. Eng. at Manchester, January, 1929.

their use has not become more general is on account of the highly increased cost. In some cases where it is necessary to use special alloy steels the cost can be reduced by dividing the superheater into two sections, consisting of mild steel tubes in which steam can be raised to a temperature of, say, 750° to 850° F., and the final superheating section consisting of the special alloy tubing in which the steam temperature is further increased to the required amount. Thus, in the 1,420-lb. pressure boilers at Mannheim Power Station, 3% nickel tubes have been used in the hottest parts. The advantages of the addition of small quantities of nickel, however, seem rather uncertain as regards superheater tubes. In this respect it may be mentioned that recent research indicates that the addition of low percentages of nickel has an adverse effect on the creep properties compared with ordinary mild steels. An alloy steel, known as Enduro metal, containing about 0·09 C, 0·34 Mn, 0·84 Si, 0·014 S, 0·021 P, 16·7 Cr, 0·19 Ni, has been tried for the last pass in certain superheaters in America, but, according to A. E. White,[6] this material appears to develop brittleness when held around 1,000° F. for a long time, and accordingly, owing to this property, its use has been discontinued in some cases. The demand for a material which is strong at high temperatures

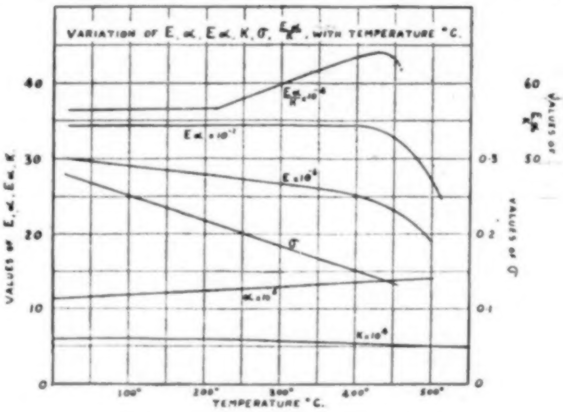


Fig. 3.

and does not scale, has led to the development of high-nickel, high-chromium steels which are austenitic in structure, and consequently can only be hardened by cold work. Most prominence has been given to an alloy of 19–18% chromium and 8% nickel. This material can be welded and machined, and tubes made from it will withstand the specified expanding, crushing, and flattening tests. It has about twice the strength of low-carbon steel at elevated temperatures, and in addition has a high resistance to oxidation. J. R. G. Monypenny,[7] however, considers that further investigation is needed before austenitic chromium nickel steel can be recommended for use at 600° C., as at this temperature the steels are particularly liable to intergranular attack by many corrosive media which have little or no action on them when they are in correctly treated condition. This seems to be borne out in practice, and the writer has been informed that while high chrome nickel alloy steel appeared at first to justify its use for high temperature service, failures have recently been experienced with this metal, due to inter-crystalline breakdown, which gradually went on without giving any warning. In all cases no bulging or splitting of the tubes occurred, but failure was caused by a sudden breakdown of a large piece of metal from the tube.

It appears that the addition of small quantities of other elements gives improved properties, an alloy containing 18% Cr, and 8% Ni, and 0·3 to 1·5% W being considered the most satisfactory composition for withstanding high temperatures or chemical attack. Tests made by J. R. G. Monypenny, however, have shown that the addition of about 1% tungsten may retard the intergranular breakdown, but under certain conditions of chemical attack the steel is not immune from this defect. Unfortunately, the price at present is almost prohibitive, being not less than twelve times that of low-carbon steels. Further, there is the likelihood of trouble in the fitting of austenitic steels on account of the difference of the coefficient of expansion from that of other materials—*e.g.*, expanding the tubes into headers. In certain cases, in order to prevent hardening or crystallisation due to being expanded into headers, short lengths of ordinary mild steel have been welded to the ends of the superheater elements, thus preventing failure at the expanded joints.

The Foster Wheeler Corporation of New York have been carrying out experiments with a chrome vanadium steel, of which the following is an approximate analysis: Cr, 0·85 to 1·05; Mn, 0·6 to 0·8; Va, 0·15 to 0·2; Si, 0·1 to 0·15; C, 0·17 to 0·22. This amount of vanadium is not sufficient to produce any vanadium characteristics in the metal, but acts as a scavenger, and gives a very close-grained metal which is exceedingly tough. Up to the present it is understood that tubes made from this steel have proved satisfactory in service, and have a much greater resistance to higher temperatures than have the ordinary carbon steel tubes.

In order to reduce cost and still have a greater factor of safety at high temperatures than that given by mild steels, attention has been devoted to the effect of small quantities of molybdenum and copper to low-carbon steels. Two tube materials which have become more prominent recently on the Continent, and the price of which is stated to be about 50% higher than that of ordinary steel tubes, are manufactured at the Thyssen Works, and are known as Th 30 and Th 31. The approximate chemical analyses of these steels are, for Th 30: Mo, 0·2 to 0·3%; Cu, 0·2 to 0·3%; C, 0·08 to 0·12%; Mn, 0·5%; Si, 0·12%, with P and S as low as possible; for Th 31 steel, the carbon content varies from 0·16 to 0·18%. The tubes are capable of withstanding the same mechanical tests as ordinary tubes. Th 30 can be welded, but for Th 31 the welding should be done by the oxy-acetylene process. Creep tests are not available at present, but the results of some comparative tests supplied by the makers are given in the accompanying table:—

Material.	Stretch Limit, Tons per Sq. In.		Ultimate Tensile, Tons per Sq. In.	
	400° C.	500° C.	400° C.	500° C.
Th 31............	17·8	15·1	32·6	24
Th 30............	11·9	10·8	25·8	19·2
3% Ni	14·7	9·5	26·9	15·9
Mild steel	8·1	5·5	20·5	11·7

The yield stresses stated in this table are not the stresses at definite yield-points. Professor Korber has shown that for soft steels the yield-point ceases at about 300° C., so that it becomes necessary to adopt some criterion of minimum plastic strain. For practical reasons he adopts a 0·2% limit, and the yield stresses given in the table correspond to what is known as 0·2% proof stress.

It is a little early to judge with any certainty how this tube material is behaving in boilers. Messrs. Vereenigte Kessel Works at Dusseldorf have built a water-tube boiler fitted with superheater tubes of this material, the working pressure of which is 52 kilogs. per sq. cm. (740 lb. per sq. in.). the tubes being exposed to a temperature of 450° C. (932° F.). The time of guarantee has already lapsed, and it is stated that the firm intend to use these tubes in future for their boilers. Similar tubes have also been fitted in a Benson boiler which has recently been installed by Messrs. Blohm and Voss for experimental purposes in a cargo vessel owned by the Hamburg Amerika Line.

6 Trans. A.S.M.E., vol. 51-1.
7 "Some Metallurgical Problems Connected with the Possible Use of Very High Steam Temperatures." (METALLURGIA, June, 1930.)

A somewhat higher alloy carbon steel has recently been introduced in this country by Messrs. Hadfield, Ltd., and is known as " Era 131." The author expressed his indebtedness to Messrs. Hadfield, Ltd., for the following information. Stated briefly, Era 131 steel, while maintaining a high strength in the range of advanced steam temperatures, 750° F. to 1,100° F., has practically the same mechanical properties as mild steel at ordinary temperatures, and cold-drawn seamless tubes fully comply with the tests specified in B.E.S.A. Spec. No. 53. It is claimed that the resistance to heat scaling is about half the rate of ordinary steel for equal temperatures, and that under long-continued heating (200 hours) at a temperature of 840° F., it suffered no deterioration in its properties. Another advantage is that the coefficient of expansion is practically the same as that of ordinary steel. The high resistance to creep of Era 131 steel compared with mild steel (0·25 C, 0·75 Mn) is indicated in Figs. 16 (*a*) and (*b*).

Tubes in Service.

Defects common in medium-pressure water-tube boilers might naturally be expected, and to a greater extent, in high-pressure boilers. As regards their frequency, they occur in the following order: internal corrosion, external corrosion, distortion, cracking or splitting, overheating due to presence of scale or to blowpipe action of the flames. The author gave some interesting particulars of experiences with water tubes in a boiler operating at high temperatures.

An interesting point which needs consideration in dealing with high temperatures is the degree in which the structure of the metal remains permanent, and, if any change of structure takes place, its effect on the durability of the metal The writer has only been able to make a few tests dealing with this point, but in the first place it might be well to refer to the change of structure that takes place when carbon steels are subjected to high temperatures, such as might arise in superheaters.

It is well known that the pearlite grains in carbon steels are made up of distinct parallel plates or lamelæ, alternatively of ferrite and cementite, and if the metal be kept for a sufficiently long time at a temperature just below its critical range, say, 600° to 700° C., the cementite tends to collect in the form of rounded particles, which is known as " spheroidisation " of the cementite or " balling " of the pearlite. The effect of spheroidising is to decrease the strength and elastic limit of the steel and to increase its ductility and softness, the degree being more marked in high- than in low-carbon steels. An example of the change of structure in an 0·16 C steel superheater tube is given by R. W. Bailey.[8] Microphotographs of the structure of the tube taken over various parts in its length indicated distinct signs of spheroidisation of the cementite at certain sections in the hottest part of the gases, showing that the temperature of the metal had been in excess of the steam temperature though general overheating was not suspected. The tube had been in actual service for 16,000 hours, the working pressure being 195 lb. per sq. in. with normal steam temperature 644° F., considerably lower operating conditions than are now in vogue. An increase in temperature would cause a more rapid change in structure, but the actual influence of spheroidisation of cementite on the creep rate has not yet been investigated. Its effect would appear to be comparatively small for low-carbon steels, and would be retarded by satisfactory annealing of the tubes subsequent to manufacture.

In order to ascertain the extent of any change in structure or alteration of the physical properties of ordinary mild-steel superheater tubes, the author has obtained a number of specimens of tubes which have been in service, and gives some of the results of an investigation on them.

8 " Creep of Steel Under Simple and Compound Stresses and the Use of High and Temperature in Steam Power Plant." (World Power Conference, Tokyo, 1929.)

Iron and Steel Foundry Practice.

(*Continued from page 22.*)

furnace, is by passing each through separate chambers built of refractory bricks, so arranged that the surface area exposed is considerable. To obtain this the bricks are chequered. Two pairs of chambers or chequers are used, and they are under control, so that air and gas are introduced from one pair at a time, the waste gases, passing through the opposite chambers, give off considerable heat, which is absorbed by the chequer brickwork. After an interval of about 30 mins. the process is reversed by operating the valve shutting off the air and gas from one side and introducing them from the other. By this means the air and gas are preheated before they enter the furnace chamber.

There are two modifications of the ordinary Siemens furnace; one in which the gas producer and furnace are combined and which has air regenerating chambers only, the gas being supplied direct from the producer; the other is a tilting furnace, in which the furnace is supported on rollers or rockers, on which it can be tilted to remove slag and to pour the metal. Although there are many different kinds of open-hearth furnaces, it is only constructive details that differ, the principles of the process do not vary. As with other types of steel furnaces and converters, both the acid and basic processes are used with the open-hearth furnace.

The illustration Fig. 5 shows the arrangement of a " Wincott " 50-ton open-hearth steel melting furnace, designed for the acid process. This furnace is in operation and during a working period of forty-eight weeks produced steel on an average coal consumption of 4.82 cwt. per ton. This is a very low consumption.

The bed of an acid furnace is prepared to form a solid and well-fitted surface before a charge is made. This is done by fusing silica sand over the bottom. To effect this the temperature is raised to about the melting point of steel. In some cases sandstone chippings are spread over the bottom, and as these melt silica sand is spread over and allowed to fuse, forming a hard, glazed surface on the bottom lining. When the first layer of sand has become glazed, more sand is added, and the process repeated until the lining has the required thickness. It is important that successive layers of sand should be well fused together.

Acid furnaces do not affect the sulphur and phosphorus contents of a charge, so that the basic process must be used when it is necessary to reduce the content of these elements. The construction of the basic open-hearth furnace does not differ from that involving the acid process, but the bottom must be made up of a basic or neutral material. Invariably, magnesite bricks are built up to form the bottom and banks, though it is cheaper to use ordinary firebricks in contact with the outer shell of the furnace before introducing the magnesite bricks. The magnesite bricks are carried up the sides to a height of about two rows above the tap-hole, the remainder of the sides and the roof being built of silica bricks. The lining of the hearth is preferably fused on in a manner similar to that for an acid hearth, and either dolomite or magnesite may be used as the basic material, but the former is usually preferred, particularly when the hot charging process is adopted. The method of making up the hearth consists, in the first place, in raising the temperature of the furnace and scattering over the magnesite bricks some finely ground basic slag. As the heat in the furnace is increased, the slag begins to flow; this forms a bond for the bricks. Calcined dolomite is then scattered over the hearth, and this is allowed to become thoroughly hard, when more dolomite is scattered over the surface. Subsequent coatings of dolomite are given, but not until the preceding one has been properly fused. When the lining is of the required shape and thickness, more basic slag is spread over the bottom, which, when fluid, gives the lining of the furnace a smooth surface.

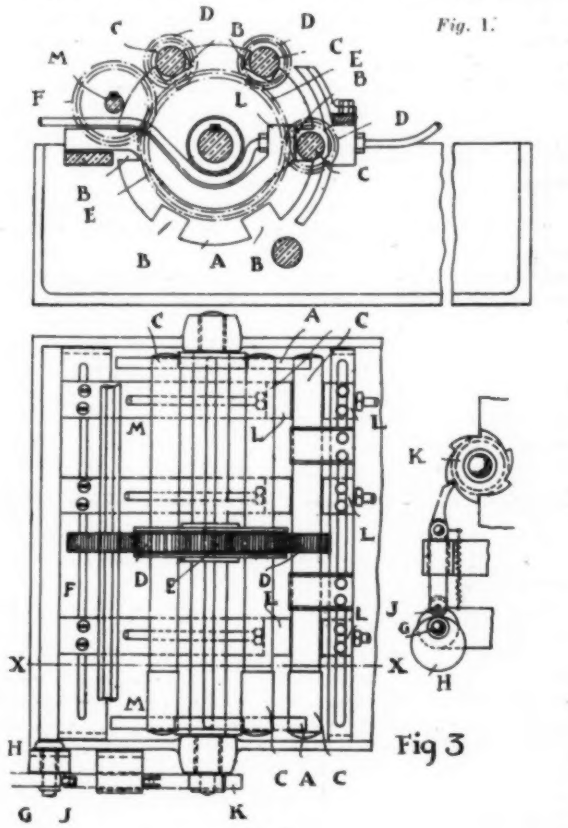
(*To be continued.*)

Some Recent Inventions.

MACHINE FOR HARDENING PARTS OF DRIVING SHAFTS.

THE accompanying illustrations, Figs. 1 and 2, show a plan and sectional elevation of a machine for hardening the bearing parts of shafts, particularly driving shafts. In this device the shafts are supported adjacent their ends in open bearings, which are carried by two end discs mounted upon a rotatable axle. The parts of shafts to be hardened are conveyed in the r tation of the discs past autogenous burners into the hardening liquid carried in a tank. Means are provided for continuously rotating the shafts about their own axes, while in the bearings of the supporting discs, and also for intermittently rotating the discs.

In the bearings formed in the side walls of the tank, an axle is journaled on which two end discs A, with open bearings B, are keyed. The shafts, the bearing points of



which have to be hardened, are loosely placed into the open bearings B of the end discs.

These shafts are indicated by C. Prior to the inserting of these shafts into the open bearings of the end discs, a spur-wheel D is keyed on each shaft, meshing with a spur-wheel E, which is loosely mounted on a bush shiftable in longitudinal direction on the axle. With the spur-wheel E meshes a spur-wheel F, shiftably mounted on an axle and driven by suitable means. On the axle G, in Fig. 3, an eccentric H is keyed, against which presses the roller J in the end of a rod suitably guided. On the other end of rod a detent is hinged which engages with a ratchet-wheel. K, rigidly mounted on one of the axles. Autogenous burners L are mounted on bridges in such a way that they can be moved, and are adapted to be secured in the adjusted positions.

In operation the axles M and G rotate, the spur-wheel F rotates the spur-wheel E, which turns the spur-wheel D, and with it the shaft C. The cam H rotates periodically the ratchet-wheel K, and, through the same, the central shaft, so that the corresponding shaft C rotates between the rows of autogenous burners L, ensuring that the bearing parts of this shaft are heated. At the next following rotation of the central shaft the shaft C, the bearing points of which have just been heated, drops into the quenching tank, and the next following shaft is brought into the range of the burners. Holding pieces are mounted on bridges, and adapted to be secured in the adjusted position, serve to prevent the shaft C from prematurely dropping out of the open bearings B of the end discs.

331,484. FRIEDRICK KLOPP, Itterbergstrasse, Wald, Rhineland, Germany, Patentee. Messrs. Chatwin and Co., Agents, 253, Grays Inn Road, London, W.C. 1. June 25, 1930.

CASTING METALS.

IN the production of iron and steel castings it is a common practice to heat the mould before the molten metal is poured in. The object of the procedure is to enable the casting to cool more slowly with a view to reducing stresses and other undesirable conditions in the casting. In general, the practice of preheating the mould has been carried out in an arbitrary manner without any definite knowledge of the physical conditions to be satisfied, with the result that advantages expected from the procedure have not always been obtained. A new method has been devised by which full advantage of preheating may be realised, which comprises the preheating of the mould to such a temperature that in the subsequent heating of the mould by the molten metal and the cooling of the metal by its contact with the mould, the parts of the mould and metal in contact with each other will reach the recalescence temperature of the metal as nearly as possible simultaneously. It will be appreciated that no precise instructions applicable to all conditions can be given, but the conditions suitable for a given mould can readily be ascertained by simple experiment.

Moulds vary both as regards the mass of sand and other materials involved in their construction, and in the thermal conductivity of such materials, and, in addition, the casting temperature of the metal varies considerably in practice, but by ascertaining the rate of cooling of the metal, and the rate of heating of a cold mould, the amount of preheating required to be given to the mould can readily be determined.

In one procedure a curve is obtained connecting time and temperature in the cooling of the metal from its casting temperature to a point below the recalescence temperature. Also, a curve connecting time and temperature is obtained for the heating of a cold mould to a convenient high temperature. From the first curve the time taken by the metal to reach the recalescence temperature is ascertained, and from the second curve the temperature attained by the mould in the same time interval is ascertained. The difference of this mould temperature and the recalescence temperature is a convenient measure of the temperature to which the mould should be preheated in order to satisfy the conditions of this invention. By heating the mould to such an initial temperature that the parts of the mould and metal in contact shall reach the recalescence temperature at as nearly the same time as possible, the inventor finds that he is able to ensure the desired conditions in the casting in a reliable manner. As is well known, the recalescence temperature is a critical one, and by arresting the cooling of the casting at that temperature, by arranging that both mould and metal shall both be at that temperature at the same time, he is able to obviate risk of setting up stresses in the metal and also to ensure that the quality of the metal when cold shall be as good as it is possible to attain.

333,494. J. E. FLETCHER, St. James's Road, Dudley, Worcestershire.

Some Contracts.

Messrs. C. A. Parsons, Ltd., of Newcastle-on-Tyne, have been awarded two contracts for electrical machinery, valued at approximately £150,000. One contract is for a 20,000-k.w. generating plant, to the order of the South African Railways while the other is for a 30,000-k.w. plant for a new power station at Copenhagen.

The Cleveland Bridge and Engineering Co., Ltd., of Darlington, have secured the contract for the construction of a bridge across the river Zambesi, and some 25 miles of railway on the south bank of the river. The Central African Railway Co., Ltd., and the Trans-Zambesia Railway Co., Ltd., have placed the contract at a total price of £1,434,337. The construction of this bridge and connecting railway, which is expected to occupy about three years, will secure direct communication between Nyasaland and the port of Beira.

The Newcastle Electric Supply Co. have placed a contract with Messrs. Reyrolle and Co., Hebburn, for a 66,000-volt switchgear for the company's new power station at Dunston. The value of the order is £125,000.

Messrs. Newton, Chambers and Co., of Chapeltown, near Sheffield, have secured an order from the Admiralty for steel tanks and fittings.

The Canadian Department of Railways and Canals has recently awarded a number of contracts in connection with the new Hudson Bay seaport at Churchill, Manitoba. The boiler-house equipment for the 2,500,000-bushel grain elevator will be supplied and installed by Messrs. Babcock-Wilcox and Goldie-McCulloch, Ltd., of Galt, Ontario, and the generator-room equipment by C. A. Parsons and Co., Toronto and Newcastle-on-Tyne. These contracts will involve the expenditure of nearly £113,000.

Ailsa Shipbuilding Co., Troon and Ayr, have contracted to build a cargo steamer for Arthur Guinness, Son and Co., Dublin. The vessel will have the following dimensions: Length between perpendiculars, 210 ft.; moulded breadth, 34 ft. 3 in.; moulded depth to deck, 19 ft. She will be fitted with refrigerating plant to ensure that the cargo will be carried at the proper temperature.

Craven's Railway Carriage and Wagon Co., Darnall, near Sheffield, have booked an order through the Crown Agents for the Colonies for carriage underframes and bogies.

The Buenos Ayres Great Southern Railway have placed orders with J. Stone and Co., Deptford, for roller-bearing axle-boxes to the value of about £8,000, and with Light Alloys, Ltd., London, for "Alpax" metal louvres to the value of over £7,000.

The English Electric Co., London, have been awarded a contract by the Buenos Ayres Great Southern Railway for traction motors for Diesel electric train units to the value of about £25,000.

An order has been placed with the Fairfield Shipbuilding and Engineering Co., Ltd., of Govan, for a new twin-screw geared turbine steamer, to be called *St. Seiriol*, which it is expected will be ready next Whitsuntide. The new steamer will have accommodation for 1,600 passengers.

The contract of Messrs. Bolton and Lakin, of Birmingham, has been accepted by Weymouth Town Council for extensive harbour improvements to provide fresh berthing accommodation for the Great Western Co.'s Channel Islands steamers, and also to deal with traffic from Northern French ports. This contract will involve an expenditure of £88,785. Weymouth Pier will be closed for three years.

The South Durham Steel and Iron Co. has secured an order for 2,000 tons of steel for the Liverpool Water Board.

Middlesex County Council have consented to the purchase by the Metropolitan Tramway Co. of 54 new tramcars at a cost of £3,000 each.

Sir W. G. Armstrong, Whitworth, and Co., Ltd., have secured an important contract for engine and hull repairs to the tanker *Narragansett*, belonging to the Anglo-American Oil Co.

The South African Steel and Iron Industrial Corporation, Ltd., supported by the Union Government, has placed contracts with three British firms for the supply of the main plant of the new works they intend to build in Pretoria. Messrs. Dorman Long tendered jointly with the German concern Demag. The latter will be responsible for steel furnaces and rolling mills, while the former will supply the steel for the fabrication of steel frame buildings. Messrs. Ashmore, Benson, Pease and Co. will supply the blast-furnace plant, and Messrs. Woodall, Duckham and Co. the coking and by-product plant. The company, which has an authorised capital of £5,500,000, was started by the Union Government, and will be financially supported by the Government, though it will operate under commercial conditions in every respect. The first consignment of the contract plant will probably be shipped to South Africa towards the end of 1931, and the company hope to be operating in full in about three years.

What is claimed to be the biggest contract of its kind to be placed in Scotland in recent years has been awarded Messrs. Yarrow and Co. It comprises an order from the London County Council for ten water-tube boilers for the tramways power station at Greenwich. The value of the contract is said to be over £200,000.

William Pickersgill, of Southwick, Sunderland, have obtained an order for a cargo steamer of 4,500 tons deadweight carrying capacity for Messrs. James Weatoll, Sunderland. The engines will be supplied by George Clark, Ltd.

A large order has been received from the Greek Government by the Fairey Aviation Co. for the supply of Fairey III. F aeroplanes. The machines are to be built with float undercarriages, and will be used as seaplanes by the Greek Air Force, which is being reorganised on the British model.

Notwithstanding serious competition from other engine firms in all parts of the world, the Greek Government have placed an order with the Napier Co. for a number of British-built Napier-Lion engines, to be installed in Fairey III. F aircraft. The Japanese Government have also placed a further order for Napier-Lion engines, which will be fitted to aircraft built in Japan.

A contract for the construction of a twin-screw tugboat has been placed by the G.W.R. Co. with C. Hill and Sons, Bristol.

Messrs. Wild-Barfield Furnaces, Ltd., have just received an order from manufacturers in this country for several Gibbons-Wild-Barfield electric furnaces. The contract is, we believe, the largest ever placed in this country for electric resistance furnaces, two of which are the largest ever built in Great Britain, each having a capacity of 7 tons.

The Clean Coal Co., London, have received an order from Newton, Chambers and Co., Sheffield, for a complete coal-cleaning plant. The plant will supply clean coal to the battery of coke ovens recently erected by Thorncliffe Coal Distillation, Ltd., at Smithy Wood, South Yorkshire.

An order has been placed with Messrs. George Turton, Platts and Co. for some thousands of steel railway buffers. The order, it is said, will require about 2,000 tons of steel. This firm is apparently in a healthy state, as Mr. G. H. Cowen, the chairman, said recently that the machine shops and forge are working day and night, and would probably have to do so during the next few months.

A contract has just been placed for the enlargement of the Central London running tunnel, the construction of escalator tunnels, and the reconstruction of the surface station with John Cochrane and Sons, Ltd., of Victoria Street, S.W. 1, at a cost of £170,000, work to be completed in just over two years.

Under their scheme for the improvement of crane equipment at Middlesbrough Dock, the London and North-Eastern Railway have placed an order with Cowans, Sheldon and Co., Ltd., Carlisle, for 37 electrically driven level-luffing wharf cranes, and with Ransomes and Rapier, Ltd., Ipswich, for nine of the same type. The total value of the contracts is £200,000.

Business Notes and News

Copper Refinery Scheme.

Negotiations are in progress between various groups with a view to the formation of a company to erect a copper refinery in England. The expenditure involved is stated to be about £2,000,000, but the initial expenditure would be considerably short of this sum. The scheme, which is to deal with Rhodesian copper, is naturally regarded as one of national importance, as, under present conditions, this country is largely dependent on America for supplies of refined copper. The Rhodesian copper mines, which have only recently been developed, are expected to become one of the world's chief sources of supply.

Various sites for the construction of the refinery have been considered, but tne decision has not yet been made. It has been stated that Mersey-side offers the best location for the industry because of the facilities offered by the Port of Liverpool. The location of the refinery will probably depend upon the capacity of the works; if it is required to meet home consumption of copper only, Liverpool district may be the most suitable, but if the capacity is to exceed home consumption, the question as between the Mersey and the Thames would undoubtedly arise, as the latter offers better facilities for export to the Continent.

Fuel Problems in the Mercantile Marine.

The future use of coal and oil by merchant vessels was discussed recently at a conference of the Institute of Fuel, held in London. The discussion followed a paper presented by Mr. S. B. Freeman, of Liverpool, on "Full Problems in the Mercantile Marine," in which he stated that there appeared to be no reason to think that oil would not be available in any required quantity in the future. Oil for passenger ships was practically indispensable, but coal was still a possibility for war vessels, which were based on countries where coal was available and oil was scarce. Speaking on the relative merits of coal and oil, Dr. W. W. Meyer, of Rotterdam, stated that while pulverised fuel system might, to some extent, raise the demand for coal, the fundamental transport difficulties of coal were not thereby relieved.

Even the development of a perfect system of pulverised coal burning to replace handling could hardly induce shipping to contribute largely to the solution of the coal problem. If bunker coal was to hold a place in competition with oil it was essential it should be supplied at a price appreciably lower than might be warranted by its calorific value. Since its cost of production had increased, coal was becoming a commodity that could not bear the cost of transportation over long distances.

Electrical Association of Women visit Siemens.

The Woolwich works of Messrs. Siemens Bros. and Co., Ltd., were visited recently by a large number of members of the Electrical Association of Women. The party comprised 120, which included four Japanese visitors. In welcoming the visitors at a luncheon held at Woolwich Town Hall, Sir William Bull said it was the first time in the history of the firm that the works had been visited by women electricians. They were proud of their works, which had grown from a small beginning, in 1858, to its present important position. Then, the firm was established in modest premises at Millbank Row, in Westminster, for the manufacture of telegraph instruments, electric batteries, regenerative furnaces, and for the development of apparatus. The accommodation at Millbank soon proved inadequate for coping with the rapidly increasing business of the company, and in 1863 it was decided to build larger and more convenient premises. Land was acquired for this purpose at Woolwich, where the works have grown continually, and the number of employees has increased from about 50 to 7,000 in recent years.

Among the earliest manufactures undertaken at Woolwich, were submarine telegraph cables. In the year 1873, Siemens Brothers first undertook the construction and laying of a cable across the Atlantic, and in order to facilitate the laying of this and subsequent cables, it was decided to build a steamer specially for this purpose. This vessel, the "Faraday," which was designed by Sir William Siemens, was launched in February, 1874. In addition to the important work which they have carried out in the field of submarine telegraphy, Siemens Brothers have played a leading part in the development of cables for telephony, electric lighting, and high-tension power transmission.

The Chemical and Metallurgical Corporation, Ltd.

As previously mentioned, a committee was appointed by the shareholders of the above Corporation on April 16 last to investigate its affairs. Although the questions relating to the previous management of this Corporation are *sub judice*, the Committee have considered it desirable to issue an interim statement to the shareholders regarding the present position. As a result of these investigations, they state that the Corporation has at its disposal sufficient funds to carry on its business according to present plants. The reorganisation of the works has resulted in substantial economies in production costs and overhead expenses, and with a restricted output of roughly 50% of its capacity, due to general trade depression, the plant has shown itself to be self-supporting and capable of profitably extending the company's position in the heavy chemical trades.

Evidently the company is deriving benefit from the recent reorganisation at Runcorn, and having ample funds at its disposal for running the plant at full capacity, it is in a good position to take advantage of a revival in trade.

The Growth of Aviation.

In an address to the British Aeronautical Society, Mr. C. R. Fairey, M.B.E., F.R.Ae.S., the Society's president, presented a summary of the "Growth of Aviation." He observed that it was not until the beginning of this century that the growth really started, and the results achieved in the short time were really remarkable; indeed, it was probable that a stage had been reached in technical aviation at which the rate of growth of recent years could not be maintained with ease. A brief survey of aeronautical history showed that there had been a change from individual research work to experiments with Government support, which had resulted in the founding of the National Physical Laboratory (Aeronautical Section) in Great Britain and a system of wind tunnel research carried out in France, under Eiffel; the Institute for Flow Research at Gottingen had been founded, and Holland, Sweden, and Italy had organised technical schools; further, the National Advisory Committee for Aeronautics had been started in America in 1915. As regards education, both the Universities of Cambridge and London had founded professorships in aeronautics before 1924, and now there was every facility for training in Great Britain and the Dominions. The biggest increase in this direction, however, had been in America, where there were now no fewer than sixty-one institutions offering aeronautical training.

Mr. Fairey stated that military aviation only interested the Society by reason of its reactions on the technical and industrial sides of aviation; but in regard to civil aviation, he said the bulk of the flying in the British Empire takes place in Great Britain, Australia, and Canada, and the outstanding fact was the expansion in the two latter countries during the last two years. "The root causes of this growth of aviation are still with us, and certainly not less to day than in the past, and so it would appear that aviation is indeed in its infancy and with an incalculable future before it."

Lincoln Arc Welding Competition.

Designers and engineers in every industry, where iron and steel forms all or a part of the manufactured product, are again given the opportunity to show their skill and ingenuity in utilising the advantages of arc welded construction. As a reward for their efforts, $17,500 wil' be awarded for the forty-one best papers submitted in the competition. The Jury of Awards, who will judge the papers entered in the competition, will be composed of the Electrical Engineering Department of Ohio State University, under the chairmanship of Professor Erwin E. Dreese, head of the department, and such others as he may select.

The purpose of this second Lincoln arc welding competition, as announced by its sponsors, the Lincoln Electric Co., Cleveland, Ohio, is to stimulate designers and engineers in every line of industry to think of the manufacture of their own products by the use of arc welding, and to increase their knowledge of the feasibility of its application. The awards will consist of forty-one prizes, to be given by the Lincoln Electric Co. to those selected by the examiners, and will be distributed as follows:—The first prize paper, $7,500; second paper, $3,500; third paper, $1,500; fourth paper, $750; fifth paper, $500; sixth paper, $250; and for the seventh to forty-first papers $100 each.

Business Notes and News—continued.

Research and Industry.

In his presidential address to the Institution of Electrical Engineers, recently, Mr. Clifford C. Paterson, O.B.E., M.Inst.C.E., director of research, General Electric Co., Ltd., spoke of the change of outlook with regard to research in the electrical industry which had taken place during recent years. "To-day," he said, "we are realising that the great march of industrial progress depends essentially on research." The great questions are: Does the industry as a whole, see the need for experimental research? Will our electricity committees and public authorities give financial support to our undertakings? And, finally, will the engineer be prepared to belittle his own capabilities by handing over his problems to a special staff? It is to the engineer that we must look for a change of outlook with regard to research in industry. The basis of efficient production is statistical study, which seldom does not fully repay.

But the cost of experimental research is high, and the importance of having such an organisation as the British Engineering Standards Association can hardly be over-estimated, for it provides the contacts between the technical sections of the industry. In the National Physical Laboratory and the Electrical Research Association, also, we have establishments which co-operate with industry in the most genuine and effective way.

Philosophy and Science.

"Youth is the time for daring adventures into new fields, and it is to men who are still young that we must look for the making of new discoveries and new inventions, and the compelling of an elderly and conservative world to accept them." So spoke Mr. Loughman St. L. Pendred in his presidential address to the Institution of Mechanical Engineers, in October. He went on to deliver "some random reflections" on philosophy and science, in which he drew attention to the fact that in engineering the great inventions are usually made by men under middle age; he quoted several examples of this among the great engineers of the last hundred years. He deplored the "specialisation" which was so general in modern youth, and the lack of the spirit of adventure. The business side of industry had got the upper hand, and business generally has little in the way of patriotic feelings: "It buys a licence to work a foreign invention, and considers itself fortunate that someone else has done all the costly experimental work." The examples of other nations who spend a lot of money on research are often held up to us, and it is said that we spend too little on it; but it must be remembered that a great deal of foreign research (notably in America) is not real scientific research, but "development" of new inventions with a view to perfection. Only a few are "engaged upon the exploration of the mysteries of nature."

"But the world," he said, "cannot do without mechanical engineers; I am confident that within a very few years there will be work for all who have brave thoughts and the courage to prosecute them."

United Steel Companies, Ltd.

The effect of the reorganisation of the United Steel Companies was indicated in the report issued recently. The sales of the company's products until March were maintained at a figure which, while below the capacity of the works, showed continued progress, and an improvement in the trading profit is the result of increased turnover and of economies effected in costs of production. A fall in sales during the June quarter had the effect of reducing the profit which was anticipated earlier in the year, but the result of the year's working indicates continued progress, and confirms the confidence of the directors in the soundness and earning capacity of the company's properties.

The United Strip and Bar Mills, Ltd., have now been absorbed by the United Steel Companies, Ltd., under the recent scheme of arrangement and amalgamation, and the reorganisation of the company's Sheffield works, being at the same time completed, the arrangements made for the management of those companies as a group during the past three years have come to an end.

A general manager of steel—Peech and Tozer, Ltd., and United Strip and Bar Mills—will be appointed in due course, and Mr. Scott-Smith, who undertook the duties of general manager of the Sheffield group during the period of reconstruction, has resumed the general managership of Samuel Fox and Co., Ltd., and undertaken, in addition, that of Daniel Doncaster and Sons, Ltd.

Metallurgy of Wire.

A series of six lectures of special interest to those engaged in the wire drawing and manipulating industries commenced at the Spenborough Technical School at the beginning of this month. The opening lecture was by Professor C. H. Desch, F.R.S., of Sheffield University, who dealt historically and descriptively with the Yorkshire wire-drawing industry, and made special reference to current progress in wire manufacture in this country, on the Continent, and in America. The remaining lectures, which are arranged for succeeding Wednesday evenings, will be given by Mr. Merrils, a Research Fellow of Sheffield University, who was formerly in charge of research at the Musselburgh works of Bruntons, Ltd. He will deal with the manufacture of iron and steel, the various processes in wire manufacture, hot and cold working, grain size, and structure and annealing effects, and he will devote some attention to special sections and special steel.

Non-ferrous Metals in Chemical Engineering.

The London Local Section of the Institute of Metals is fortunate in that the President of the Institute, Dr. Richard Seligman, has agreed to read a paper at the next meeting of the Section. The paper is entitled, "Some Non-ferrous Metals in Chemical Engineering." It will be presented at the Royal School of Mines, South Kensington, on Thursday, November 20, at 8 p.m. Tickets may be obtained on application to the hon. secretary of the Local Section, Mr. J. McNeill, the Mond Nickel Co., Ltd., Imperial Chemical House, S.W. 1.

Catalogues and Other Publications.

The October issue of the *Nickel Bulletin* contains a well-illustrated article on nickel coinage, and the expansion problem in regard to aluminium alloy pistons is discussed. It is interesting to note that the Mond Nickel Co. have increased their travelling exhibits. "The Versatility of Nickel" proved so popular last year as an exhibit suitable for display at colleges, technical institutions, schools, etc., in connection with open nights and special functions, that they have added other two exhibits of similar character. One illustrates the "Extraction of Nickel by the Mond Process," and the other the "Properties and Application of Nickel and its Alloys." With the experience gained last year the company have been able to form collections which, we feel sure, will be both interesting and informative. Further information is available on application to the Mond Nickel Co., Ltd., Imperial Chemical House, Millbank, London, S.W. 1.

Ferodo, Ltd., Sovereign Mills, Chapel-en-le-Frith, have sent us three brochures dealing with Ferodo linings. One of them is devoted to brake and clutch linings for use in mining and engineering, another to similar linings for touring and commercial vehicles, and the third to linings for friction-wheel transmission, which are of special composition, different in character to the brake and clutch friction fabrics.

An attractive brochure, dealing with the use of precision grinding machines in railway-shop practice, has been sent to us by the Churchill Machine Tool Co. The book is in two parts, the first part illustrating machines in operation, and the second giving specifications of present models. The same firm has also issued several new pamphlets dealing with brake-drum, crankshaft, and tramway wheel grinding machines. These may be had on application to their offices at Broadheath, Manchester.

Tough alloy steel containing high percentages of nickel and chromium has been found the best material for road studs. It has a high tensile strength, to give long life, and is tough enough to withstand all road shocks; but to develop the strength of the metal, it is preferably forged. We have received a folder dealing with rustless steel road studs from D. Doncaster and Sons, Ltd. These studs are drop-forged; the steel, dies, and studs are made throughout in the same works. Further particulars are available on application to this firm at Penistone Road, Sheffield, or to the United Steel Companies, Ltd.

The Butler Machine Tool Co. Ltd. have prepared a little booklet containing genuine photographs of their latest productions, and we have no doubt that machine tool users would treasure this as a very useful illustrated record of modern machines.

A Brief Review of Modern Shipbuilding

"I REGRET that no address can contain the panacea for the troubles threatening the engineering and shipbuilding industry of this country," said Mr. John McGovern, in his presidential address to the North-East Coast Institution of Engineers and Shipbuilders at Newcastle-on-Tyne. He went on to deliver a paper on "Modern Shipbuilding," in which he reviewed the district facilities for scientific training, now augmented by the completion of the Constantine Technical College at Middlesbrough, which provides courses of instruction in engineering, metallurgy, commerce, and other subjects. As regards research work, he observed that a second experiment tank was to be constructed to relieve the pressure of work on the William Froude tank, and that investigation was to proceed further on the subject of "wake," since Mr. G. S. Baker had presented to the Institution the results of his research on that subject. In dealing with the efficiency of the modern ship, Mr. McGovern said that there was no doubt that the modern ship was capable of carrying more efficiently than pre-war vessels; furthermore, never before had our engineers offered such a wide variety of economical power installations to suit all conditions of service. The advent of oil fuel had influenced shipping profoundly, owing to its displacement of a large amount of faster, better-class, coal-burning tonnage. Both coal and oil have their proper spheres of employment, and the coal-fired steamship offers the cheapest method of propulsion available. Shipyards and engine works had benefited largely through the development of the oil tanker and the internal-combustion engine, while another new development had been in the conversion of large vessels for the whaling industry, the contracts for which had relieved the situation in some of the North-East Coast yards. He anticipated that the investigations now proceeding might result in giving a new lease of life to steam as a prime mover, for there seemed to be considerable economy in the use of superheated steam plants, which have the advantage that conversion from coal to oil, or *vice versa*, may be made as desired.

Meanwhile, the progress of the marine motor engine continues. A large proportion of the new tonnage building consists of tankers, for which the oil-engine is particularly suitable. Mr. McGovern said that he felt very loth to attempt any prophecies, as so many other prophets had achieved small measure of success; for example, in 1837, at a meeting of the British Association in Bristol, Dr. Lardner declared that "to cross the Atlantic by means of steam was as impossible as a voyage to the moon!"

"Alumbro" Condenser Tubes.

"Alumbro" is an aluminium brass employed in the manufacture of condenser tubes. It contains 76% copper, 22% zinc, and 2% aluminium, and its development for condenser-tube work is the outcome of research work conducted originally by the British Non-Ferrous Metals Research Association on the effect of aluminium on brass.

Until recent years, there has been a great deal of prejudice against the inclusion of aluminium in brass by reason of the difficulty experienced in obtaining sound castings, and also because of the widespread belief that aluminium brasses possessed the undesirable tendency to season-crack. An improved method of casting, which enables the metal to be poured into the mould without turbulence or splashing, ensures the production of sound castings, and in regard to season-cracking, experiments that have been carried out by the British Non-Ferrous Metals Research Association, and in the laboratories of I.C.I. Metals, Ltd., have effectually exposed the fallacy of the theory that aluminium increases the tendency of brass to season-crack. It is also interesting to note that tests have shown that the resistance of brasses to corrosion is considerably improved by the addition of aluminium, and that aluminium brass of high copper content is superior from a corrosion-resisting point of view to that of lower copper content.

A booklet describing the results of intensive experiment on the effect of aluminium on brass, and leading up to the manufacture of "Alumbro" condenser tubes, has been published by I.C.I. Metals, Ltd., Millbank, London, S.W. 1, which is both interesting and informative.

IRON AND STEEL REPORT.

THE margin between British and Continental iron and steel prices has long been a very wide one, but the falling movement during the past few weeks brought rates for imported materials to levels which, in the case of certain varieties at all events, are well below pre-war rates. It was probably this latest decline which was responsible for the private member's motion, introduced by Major Thomas in the House of Commons early this month, urging the Government "to take immediate action to stem the continuous decline in the activities of the British iron and steel industry, with its resultant increase in unemployment." The motion itself was much less contentious, politically, than the arguments employed in the discussion, and was accepted on behalf of the Government by the Parliamentary Secretary to the Board of Trade, without, however, any indication as to what the line of action would be.

Meanwhile, in neither British nor Continental steel can trading conditions in the markets in this country be described as even moderately good. The weakest spots, so far as bulk business is concerned, are the shipbuilding and constructional branches, neither of which, in the present state of their order books, are in a position to take anything like their normal quantities of steel. In the locomotive building industry, in at least one important individual instance, there has latterly been some measure of improvement, but it has not by any means been general, and in the aggregate the tonnage of plates and other steel materials going into consumption is below what it was a few months ago. Forward transactions in heavy steel products, quite apart from the prevailing conditions at the consuming end, continue to be influenced by the price factor. Very few buyers, in spite of the fact that the Steel Association recently reaffirmed the scheduled rates for controlled products, have sufficient faith in the stability of prices to enter into forward contracts of any weight, and consequently there is almost a general tendency, which has become more pronounced of late, to place new business on the basis of current rolling programmes. The state of affairs at the rolling mills, even the best situated normally, can be gauged from the fact that delivery of most kinds of British steel is obtainable now at very short notice.

As has been indicated, there has been no change in the prices of controlled products, but further weakness has developed in boiler plates and small re-rolled bars, the former being currently quoted at round £9 7s. 6d. per ton, and the latter at down to £7 7s. 6d. At times during the past month a fair business has been reported in high-carbon and alloy steels.

Midland foundry iron makers are less free from the threat of Continental competition than they have been previously, and offers of the latter have recently been as much as 8s. per ton below Derbyshire and Staffordshire prices for delivery into certain areas. So far, however, there have been no retaliatory reductions by the home makers, who reiterate that their quotations are already below the cost-of-production level in the case of the majority of plants. So far as the largest producers in the Midlands are concerned, the heavy demand for pig iron for use in associated pipe foundries helps to adjust the position, but the fact remains that the stocks held by most makers, even allowing for a reduced rate of output, are growing.

Apart from one or two firms whose deliveries to general foundries are said to have been up to the level of the past three months or so, there has been a slight decline in the aggregate movement into consumption compared with the late summer, and little immediate prospect of the position improving. As in the case of steel, there is no disposition among users to book ahead, and, generally speaking, commitments are more closely confined to prompt transactions than they have been for a long time.

An original illustration on page 7 shows a distant view of the Chemical and Metallurgical Corporation's work, situated between the Mersey (in the background) and the Manchester Ship Canal, on which they have their own loading jetty.

MARKET PRICES

ALUMINIUM.

99% Purity		£85 0 0
Castings, 2.L5 Alloy	lb.	1/3–1/8
,, 2.L8 ,,	,,	1/4–1/9
,, Silicon ,,	,,	—

ANTIMONY.

English	£36 0 0
Chinese	25 10 0
Crude	22 0 0

BRASS.

Solid Drawn Tubes	lb.	9¾d.
Brazed Tubes	lb.	11¾d.
Rods Drawn	,,	9¼d.
Wire	,,	8d.
*Extruded Brass Bars	,,	5d.

COPPER.

Standard Cash		£42 17 6
Electrolytic		43 5 0
Best Selected		44 10 0
Tough		44 0 0
Sheets		73 0 0
Wire Bars		45 3 0
Ingot Bars		45 5 0
Solid Drawn Tubes	lb.	11d.
Brazed Tubes	,,	11d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	£0 2 6
‡Ferro Tungsten	,,	0 2 3
§ Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.		
2-4% Carbon, scale 11/- per unit	ton	30 10 0
4-6% Carbon, scale 7/- per unit	,,	23 2 6
6-8% Carbon, scale 7/- per unit	,,	22 12 6
8-10% Carbon, scale 7/- per unit	,,	22 0 0
§ Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit	,,	33 0 0
§ Guar. max. 1% Carbon, scale 13/6 per unit	,,	36 15 0
§ Guar. max. 0.7% Carbon, scale 15/- per unit	,,	40 10 0
‡Manganese Metal 96-98% Mn.	lb.	0 1 3
‡Metallic Chromium	,,	0 2 7
§ Ferro-Vanadium 25-50%	,,	0 12 9
§ Spiegel, 18-20%	ton	7 5 0
Ferro Silicon—		
Basis 10%, scale 3/- per unit	ton	5 17 6
20/30% basis 25%, scale 3/- per unit	,,	7 17 6
45/50% basis 45%, scale 5/- per unit	,,	11 10 0
70/80% basis 75%, scale 7/- per unit	,,	18 0 0
90/95% basis 90%, scale 10/- per unit	,,	25 6 0
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	14 0 0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0 0 6
§ Ferro Phosphorus, 20-25%	ton	15 12 6

FUELS.

Foundry Coke—	
S. Wales Export	£1 7 6 to £1 15 0
Sheffield Export	0 17 0 to 0 18 6
Durham Export	1 4 0 to 1 6 0
Furnace Coke—	
Sheffield Export	£0 17 0 to £0 18 6
S. Wales ,,	17 6 to 1 0 0
Durham	0 14 0 to 0 14 6

GUN METAL.

Commercial Ingots		£65 0 0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0 1 0
*Cored Bars	,,	0 1 2

LEAD.

Soft Foreign	£15 16 3
English	17 5 0

MANUFACTURED IRON.

Scotland—	
Crown Bars	£10 5 0
N.E. Coast—	
Rivets	11 10 0
Best Bars	11 5 0
Common Bars	10 15 0
Lancashire—	
Crown Bars	10 5 0
Hoops	13 0 0
Midlands—	
Crown Bars	10 7 6
Marked Bars	12 10 0
Unmarked Bars	—
Nut and Bolt Bars	9 0 0
Gas Strip	10 17 6
S. Yorks.—	
Best Bars	11 0 0
Hoops	12 0 0

PHOSPHOR BRONZE.

*Bars, Tank brand, 1 in. dia. and upwards	lb.	1/-
*Cored Bars	,,	1/2
†Strip	,,	1/-
†Sheet to 10 W.G.	,,	1/0½
†Wire	,,	1/0⅞
†Rods	,,	1/0½
†Tubes	,,	1/5¼
†Castings	,,	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—	
Hematite M/Nos.	£3 17 0
Foundry No. 1	3 19 0
,, No. 3	3 16 6
N.E. Coast—	
Hematite No. 1	3 11 6
Foundry No. 1	3 6 0
,, No. 3	3 3 6
,, No. 4	3 2 6
Cleveland—	
Foundry No. 3	3 3 6
,, No. 4	3 2 6
Silicon Iron	3 6 0
Forge No. 4	3 2 0
N.W. Coast—	
Hematite	4 8 6
Midlands—	
N. Staffs Forge No. 4	3 8 6
,, Foundry No. 3	3 13 6
Northants—	
Forge No. 4	3 5 0
Foundry No. 3	3 10 0
Derbyshire Forge	3 8 6
,, Foundry No. 3	3 13 6
West Coast Hematite	4 6 6
East ,, ,,	4 3 6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6 0 0 to £7 10 0
Bars, hammered, basis	£17 10 0 ,, £18 10 0
Blooms	£10 0 0 ,, £12 0 0
Keg steel	£32 0 0 ,, £33 0 0
Faggot steel	£20 0 0 ,, £24 0 0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£37 0 0
,, Braziery	34 0 0
,, Wire	—
Brass	26 0 0
Gun Metal	38 0 0
Zinc	7 10 0
Aluminium Cuttings	51 0 0
Lead	11 0 0
Heavy Steel—	
S. Wales	2 12 6
Scotland	2 10 0
Cleveland	2 5 0
Cast Iron—	
Lancashire	2 7 6
S. Wales	2 12 6
Cleveland	£2 11 0 to 2 13 6
Steel Turnings—	
Cleveland	1 17 6
Lancashire	1 7 6
Cast Iron Borings—	
Cleveland	1 10 0
Scotland	1 15 0

SPELTER.

G.O.B. Official	—
Hard	£11 10 0
English	15 10 0
India	12 15 0
Re-melted	13 0 0

STEEL.

Ship, Bridge, and Tank Plates—	
Scotland	£8 15 0
North-East Coast	8 15 0
Midlands	8 17 6
Boiler Plates (Land), Scotland	10 0 0
,, ,, (Marine) ,,	10 10 0
,, ,, (Land), N.E. Coast	10 0 0
,, ,, (Marine) ,,	10 10 0
Angles, Scotland	8 7 6
,, North-East Coast	8 7 6
,, Midlands	8 7 6
Joists	8 10 0
Heavy Rails	8 10 0
Fishplates	12 0 0
Light Rails	8 17 6
Sheffield—	
Siemens Acid Billets	9 10 0
Hard Basic	9 12 6
Medium Basic	8 2 6
Soft Basic	6 10 0
Hoops	9 15 0
Manchester—	
Hoops	9 15 0
Scotland, Sheets 20 W.G.	9 10 0

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten	lb.	3/-
Extras		
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to 3/16 in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ⅜ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash		£111 10 0
English		112 10 0
Australian		114 5 0
Eastern		118 5 0
Tin Plates I.C. 20 × 14	box	17/-
Block Tin Cash		£111 5 0

ZINC.

English Sheets	£24 0 0
Rods	28 0 0
Battery Plates	21 0 0

* McKechnie Brothers, Ltd., quoted Nov. 10. † C. Clifford & Son, Ltd., quoted Nov. 10. ‡ Murex Limited, quoted Nov. 12.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices :—Wrought Iron Bars, £10 5s. 0d. ; Mild Steel Bars, £7 7s. 6d. ; Wrought Iron Hoops, £12 ; Best Special Steel Baling Hoops, £9 5s. 0d. ; Soft Steel Hoops (Coopers' and Ordinary Qualities), £8 15s. 0d. ; C.R. & C.A. Steel Hoops, £12 0s. 0d. to £13 0s. 0d ; "Iris" Bars, £8 15s. 0d. All Nett Cash. Quoted Nov. 10.

§ Prices quoted Nov. 10, ex warehouse.